REPORT RESUMES

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JOB PERFORMANCE AIDS AND THEIR IMPACT ON MANPOWER UTILIZATION.

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DESCRIPTORS- *TASK PERFORMANCE, AUDIOVISUAL AIDS, INFORMATION UTILIZATION, *JOB SKILLS, *INSTRUCTIONAL AIDS, ANNOTATED BIBLIOGRAPHIES, REFERENCE MATERIALS, MANUALS, MANPOWER UTILIZATION, TRAINING, ELECTRONICS, NURSING, RESEARCH NEEDS, JOB PERFORMANCE AIDS,

THE PURPOSE OF THE STUDY WAS TO REVIEW AND SYNTHESIZE THE RESULTS OF RESEARCH ON JOB PERFORMANCE AIDS AND EXPLORE THEIR CURRENT AND POTENTIAL ON INDUSTRIAL MANPOWER UTILIZATION. JOB PERFORMANCE AIDS ARE AUXILIARY INFORMATION STORAGE DEVICES WHICH PRESENT JOB INSTRUCTIONS OR REFERENCE DATA FOR USE BY THE EMPLOYEE DURING THE COURSE OF HIS JOB PERFORMANCE. AN UNDERLYING ASSUMPTION WAS THAT JOB PERFORMANCE AIDS COULD BE VIEWED AS A MAJOR TOOL FOR MATCHING JOB REQUIREMENTS WITH AVAILABLE MANPOWER RESOURCES. FINDINGS WERE DERIVED FROM A REVIEW OF THE LITERATURE AND FROM A FIELD STUDY OF PERFORMANCE AID UTILIZATION IN 12 ELECTRONICS ASSEMBLY ORGANIZATIONS AND PATIENT CARE AREAS OF 12 HOSPITALS. THE RESULTS SHOWED THAT DEPENDING UPON THEIR DESIGN AND USAGE, JOB PERFORMANCE AIDS COULD COMPENSATE FOR LACK OF TRAINING AND EXPERIENCE, IMPROVE JOB QUALITY, AND INCREASE PRODUCTIVITY. THE IMPACT OF JOB AIDS WAS PARTICULARLY APPARENT IN COMPLEX OR LENGTHY TASKS, DIMINISHING IN EFFECTIVENESS AS TASKS WERE SUBDIVIDED INTO SHORT CYCLE, REPETITIVE OPERATIONS. A BASIC FRAMEWORK FOR ADVANCING THE FIELD OF JOB PERFORMANCE AIDS WAS PROPOSED, AND A SERIES OF RESEARCH QUESTIONS WAS LISTED. IT WAS RECOMMENDED THAT THE DEPARTMENT OF LABOR CONSIDER THE ROLE IT MIGHT PLAY IN OVERCOMING THE LACK OF COMMUNICATIONS WHICH UP TO NOW HAS HINDERED THE DEVELOPMENT OF THE JOB PERFORMANCE AID FIELD. (ET)

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PREFACE

This report was prepared under Contract 81-05-67-06 between the Department of Labor, Office of Manpower Policy, Evaluation and Research and the Philco-Ford Corporation Western Development Laboratories. The study was conducted in the Personnel Subsystems Department, Mr. T. W. Reiland, Manager. Miss Catherine Christgau served as contract monitor for the Department of Labor.

The authors are grateful to the many individuals and organizations that supplied information so generously during this exploratory study. Particular appreciation is extended to the Palo Alto-Stanford Hospital Center; in particular to Mr. Samuel Virts, Assistant Director, Employee Relations-Communications and Training; to Mrs. G. Darlene Lutz, R. N., Director, Nursing Service; and to Miss Marjorie Keys, R. N., Supervisor of In-Service Education and her staff.

Among the Philco-Ford personnel who contributed to this report, special recognition is due Dr. R. A. Goldbeck for his review of the draft report and his help in the preparation of the annotated bibliography. Mr. James Casalegno was also of major assistance in developing the bibliography and taking care of the many details involved in producing the final report. Mr. Wilbert Cox participated in the early study preparations and provided helpful comments on the final manuscript.

SUMMARY

The present investigation was designed to review and synthesize the results of job performance aid research and application and to explore the current and potential impact of such aids upon industrial manpower utilization. The study involved a review and analysis of relevant research literature and reports of job aid applications, summaries of which are included in an appendix. In addition, a field study was conducted of job performance aid usage in two distinctly different occupational areas: electronics assembly and patient care. Interviews were conducted in 24 organizations, twelve representing each occupational area.

The results show that, depending upon their design and usage, job performance aids can compensate for lack of training and experience, improve job quality, and increase productivity. Evidence is generally lacking concerning the extent to which job performance aids can compensate for basic aptitude deficiencies. The impact of job aids is particularly apparent in complex or lengthy tasks, diminishing in effectiveness as tasks are subdivided into short cycle, repetitive operations.

A basic framework for advancing the field of job performance aids is proposed and discussed. Recommendations are made for comprehensive job aid development and demonstration efforts. On a more basic level, a series of research questions are posed, the solutions to which would contribute to better understanding and long-term utilization of job aids.

Finally, it is recommended that the Department of Labor consider the role it might play in overcoming the significant lack of communications which up to now has apparently hindered the development of the job performance aid field. Specific suggestions are included for fostering improved communications in the job aid field.

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INTRODUCTION

One of the major goals of the research sponsored under the Manpower Development and Training Act is to contribute to the development of new perspectives and solutions to manpower problems. As a result, a wide variety of research has been conducted on many of the specific problems associated with the impact of technological changes. Solutions are being sought to the employment problems of the non-white, the older worker, the handicapped, and other disadvantaged groups. At the core of many of our manpower problems is the very basic question of how can we improve the effectiveness and the efficiency of our methods for achieving satisfactory human performance in a work environment with a rapidly accelerating rate of change. The wide-scale attack upon educational and training problems testifies to the vital concern for achieving a better balance between human performance capabilities on the one hand and changing job demands on the other.

The present study is concerned very directly with the improvement of methods for facilitating human performance; but its focus is not upon the area generally defined as training. Rather, a primary objective of the study is to define the field of job performance aids as an element in an overall human performance system and to explore the potential of the field for improving our efforts in achieving adequate job performance.

While the nature of job performance aids will be explored in depth throughout the report, they can be defined here as auxiliary information storage devices which present job instructions or reference data for use by the employee during the course of his job performance. For purposes of this discussion, the particular form and construction of the performance aid is not important. Whether it be a checklist, a nomograph, or a computerized job information system, the main consideration is that the "device" assist the worker by storing or otherwise handling information.

Accordingly, other types of equipment used on the job; e. g., tools, jigs and fixtures, etc., are not included in our definition of job performance aids. Job performance aids are designed specifically to facilitate job performance by relieving certain job demands; for example, the demand for memorizing complex, lengthy, or infrequently used job sequences or supporting reference formulas, values, etc.

This report describes an exploratory study of job performance aids and their current and potential impact upon manpower selection, training, and utilization practices. Specifically, the research method involved a comprehensive review and analysis of research and development reports, supplemented by a field study of performance aid utilization in two selected occupational areas: electronics assembly and patient care. The following section describes the basic concept of job performance aids. Research and application literature covering both military and industrial job aid experience is then examined. The next two sections describe the procedures used and the results obtained from the electronics assembly and patient care surveys. In order to provide a foundation for further study, possible bases for categorizing job performance aids are proposed and relationships between such aids and the training area are discussed. Tentative conclusions are then drawn concerning the impact of performance aids upon training, selection, job quality, and productivity. The resulting implications for routine tasks and for technical work areas are discussed. Recommendations for research and development are provided and policy implications are then examined. Finally, to provide a foundation of reference information and to enable the reader to identify particular reports worthy of reading, an annotated bibliography of publications relevant to the job performance aid field is provided.

THE CONCEPT OF JOB PERFORMANCE AIDS

One of the most common examples of job performance aids is the instruction sheet that accompanies an unassembled toy or piece of furniture. Properly developed, this little sheet of paper can make the difference between virtual chaos and achieving a rather complex new feat (e. g. , bicycle assembly) without any special training and with only a minimum of previously acquired skills, such as reading and simple tool handling. And yet as frequently as we have been confronted with specific illustrations of good and, more often, inadequate performance aids there has been pitifully little effort devoted toward exploiting the area of external information storage and presentation as an integral part of human work performance development.

Rather than forming a conscious part of job design, most of the efforts to provide information support appear to have been approached as an afterthought. Consequently, job aids are more often remembered for their frustrating inadequacy instead of for their contribution to fostering human performance. Their potential for influencing such decisions as what level of personnel are required for job performance and how much training must be provided before an individual can function adequately on a job has largely been ignored in the industrial work area.

It is not meant to imply that the field of performance aids has been completely disregarded in the industrial work area. There are certainly many examples of effective job aids in use today. The lubrication chart in the filling station, by specifying the activities to be followed and showing the location of the parts to be lubricated for each model and year of car, is an excellent example of a type of job aid which substitutes for the lengthy training and experience that would otherwise be required if the mechanic had to rely exclusively upon his memory to accomplish such tasks. With only a minimum of training, any gas station attendant utilizing the job performance aid can lubricate most vehicles to the same level of performance, and very likely with greater reliability, than would be achieved by a skilled mechanic who had to rely entirely upon his previous training and past experience.

Despite such examples, job performance aids as a special field have been virtually overlooked. This omission can be detected in our efforts to solve the pressing manpower problems cited in the previous section. Whether or not expressly stated, the assumption that underlies most of our efforts to combat poverty and unemployment is that, given a particular set of job requirements, there are only two vehicles for obtaining human work performance - selection and training. This assumption is illustrated very simply in Figure 1. If we extend this concept to its logical conclusion, it can be seen that to the extent individuals enter the job market lacking in specific job knowledges we have no alternative but to lengthen the training period or in other ways expand the scope of training as illustrated in the figure.

The almost total commitment to training as the solution to the problems of the disadvantaged can be seen underlying practically every major project associated with the Poverty Program. Without in any way detracting from the legitimate emphasis upon training and the need to expand and improve our training efforts, the hypothesis underlying the present study is that training is not the only vehicle for aligning job requirements with manpower resources. The assumption that job performance aids can be viewed as a major tool for obtaining human performance provided the major stimulus for the work described in this report.

Adding another element to performance development can provide greater flexibility and broadened perspective toward the solution of manpower problems. Effective job performance aids, by reducing the information retention load in a job, can ideally serve as an alternative to the continual expansion of training that must otherwise result as jobs become more complex or as the input quality of the work force decreases. The potential effect of job performance aids upon selection and training is illustrated in the model shown in Figure 2.

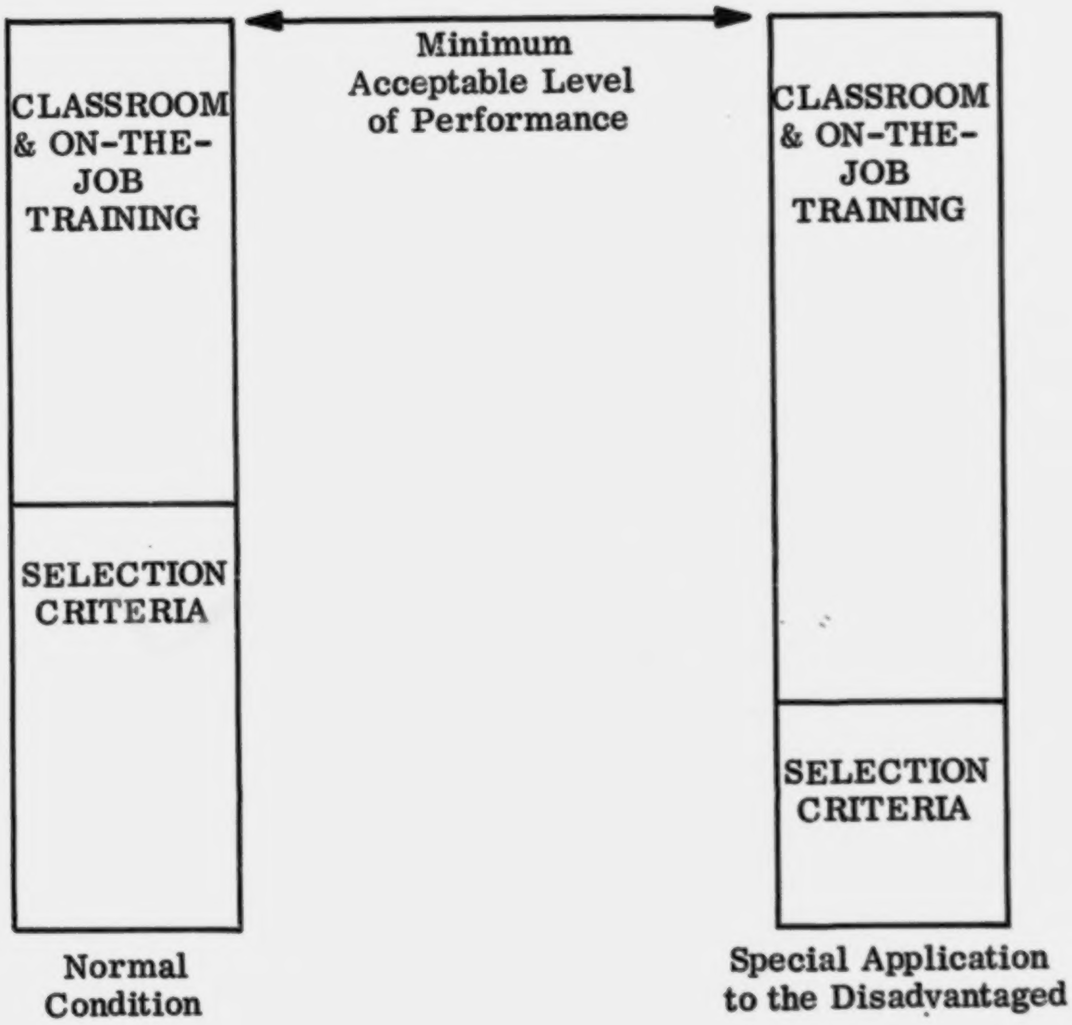
Minimum
Acceptable Level
of Performance
CLASSROOM & ON-THE-JOB TRAINING
SELECTION CRITERIA
Normal Condition
CLASSROOM & ON-THE-JOB TRAINING
SELECTION CRITERIA
Special Application to the Disadvantaged

FIGURE 1

HYPOTHETICAL ATTAINMENT OF JOB PERFORMANCE REQUIREMENTS BASED ON SELECTION AND TRAINING ONLY

SATISFACTION OF JOB PERFORMANCE REQUIREMENTS

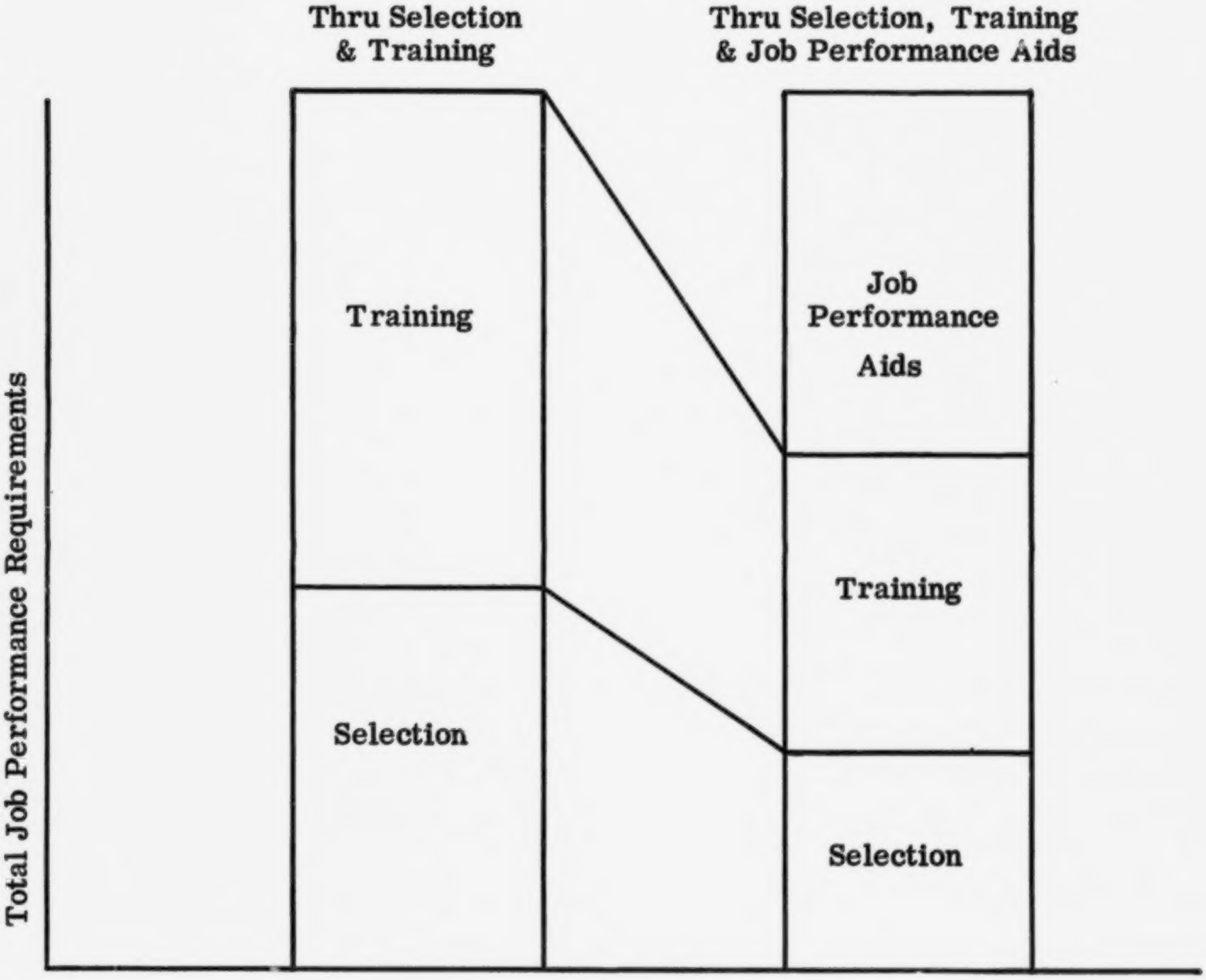
Thru Selection & Training
Thru Selection, Training & Job Performance Aids
Total Job Performance Requirements
Training
Selection
Job Performance Aids
Training
Selection

FIGURE 2

POTENTIAL EFFECT OF JOB PERFORMANCE AIDS UPON SELECTION AND TRAINING

From this model, one can envision that effective job performance aids can be expected to result in:

- Reduction in training time
- Lowering of selection standards

Other potential benefits include:

- Improved quality and reduction in job errors
- Increased reliability of job performance
- Greater productivity
- Increased scope and complexity of tasks performed

It must be stressed that the purpose of the foregoing discussion was to provide an initial structuring of the field of job performance aids and to cite some of the contributions which conceivably can be gained from such an approach. While at this stage the concepts and contributions of job aids are largely theoretical, they are not without some basis in empirical research and practical application. It is the goal of this report to attempt to bring together the relevant research and some of the more systematic applications of job performance aids and from this to provide a basis for a better assessment of the field as a tool for improved manpower utilization.

COMPARISON OF TRAINING AIDS AND JOB PERFORMANCE AIDS

As indicated earlier, job performance aids are defined as documentation or auxiliary information storage and presentation devices used on the job to provide instructions and reference information. They are designed to facilitate employee performance through direct usage either during the course of task performance or perhaps immediately prior to beginning a task. A handbook of automobile engine specifications, for example, is a job performance aid. Its prime function is to serve as a reference guide for mechanics engaged in engine adjustment and repair. While students should be taught how to use the aid efficiently, one would not normally use such a handbook in the classroom for the purpose of teaching students the specifications of all engines. On the other hand, a mock-up or other display showing the flow of gasoline in an automobile engine is clearly a training aid and is not intended for use by mechanics on the job during engine repair.

While indeed individuals may learn certain things during their use of job aids; the major function of such aids is to support job performance and not to achieve long term retention. In contrast, classroom training aids, some of which may nevertheless be appropriate for on-the-job use, have the major goal of fostering the learning of a task. Of course, it is obvious that job performance aids can frequently be used to advantage in the classroom to develop skills and foster attitudes conducive to on-the-job usage. Table 1 presents a rough comparison of the primary functions and key features of training aids as compared with job performance aids.

TABLE 1

CLASSROOM TRAINING AIDS VS JOB PERFORMANCE AIDS

BASIC CHARACTERISTICS	TRAINING AIDS	JOB PERFORMANCE AIDS
PRIMARY FUNCTION	FACILITATE LEARNING	SUPPORT JOB PERFORMANCE
CONDITIONS OF USE	IN CLASSROOM - DURING TRAINING SESSION	ON THE JOB-DURING ACTUAL JOB PERFORMANCE
KEY FEATURES	SMALL SEGMENTS OF INFORMATION	LARGER SEGMENTS OF INFORMATION
	REPETITION OF SUBJECT MATTER	RAPID ACCESS BY JOB INCUMBENT
	ATTENTION GETTING	ACCEPTANCE BY JOB INCUMBENT
	USED BY, OR UNDER DIRECTION OF, CLASSROOM INSTRUCTOR	CONVENIENCE OF USE BY JOB INCUMBENT
	NO CHANGE IN TASK CONTENT	MAY MODIFY TASK CONTENT

Literature Review

REVIEW & ANALYSIS OF JOB PERFORMANCE AID RESEARCH & APPLICATION

The first phase of the study, which was continued up until the drafting of the report, involved an intensive review and critical analysis of the reported research and application of job aids. Major reference indexes were reviewed both in the scientific and technical area and in the business and general publication area as well. The specific sources of reference information are listed in Appendix B. Articles that appeared relevant to the subject area were identified and were obtained for review and analysis. Despite the fact that the relevant literature is traceable back nearly 15 years, much of it consisting of governmental reports, in only a few instances was it necessary to rely upon secondary sources of information.

The literature surveyed can be categorized roughly into two areas: (a) military research and application and (b) civilian applications. By far the greatest amount of applicable research was sponsored by the military, primarily the Air Force. With but a few exceptions, the articles in the civilian publications dealt primarily with reports of the development and utilization of specific performance aids. Unfortunately, as will be discussed in depth later, the claims made in the trade publications for the efficacy of various types of job aids were generally unsubstantiated and accompanied by very little supporting data upon which to base an evaluation.

Two other types of information served as an input to the research and application review phase. To ensure that the latest findings from recently completed research and on-going studies were reflected in the report, contacts were established and information obtained directly from investigators currently working in the job performance aid field or related areas. A list of the individuals and organizations contacted is provided in Appendix C.

In addition, reports and other descriptive material were accumulated on a variety of job performance aid equipment and other media currently in use or expected to be available for use shortly. Where it appeared worthwhile, personal contacts were established with representatives of the manufacturers and distributors of equipment applicable or potentially applicable for use as job aids. In addition to providing the latest hardware information, these contacts also served as a source of information for the field study.

AIR FORCE RESEARCH AND APPLICATION

By far the major contribution to job performance aid research has been made by the Air Force. More than any other organization, the Air Force and its supporting contractors have identified and defined the job performance aid field as an important element in system effectiveness. Understandably, the research has been directed toward the problems associated with complex weapon systems.

The first of a lengthy list of reports on the conduct of research and development in this area appeared in the mid 1950's with a report by Berkshire[1] (5) describing the field evaluation of an aid for troubleshooting a portion of a radar set. From 1954 to 1958 the Air Force Personnel and Training Research Center (AFPTRC) sponsored a sizable number of studies most of which, like Berkshire's, dealt with the development of sample job aids for particular systems or subsystems. The primary emphasis in the research was upon simplification of troubleshooting, including research on what information should be displayed and on determining optimum strategies for troubleshooting. Typical of this period is the work of Warren et al, in developing and evaluating a symptom-malfunction index as a troubleshooting aid for complex electronic systems (53).

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[1] Numbers in the parenthesis direct the reader to the specific publication indexed and abstracted in Appendix A.

During this period, the Maintenance Laboratory of AFPTRC developed a major research program to explore the possibilities of materially decreasing technical training and achieving important increases in reliability of technician performance through improved methods for communicating technical information in operational situations. The program was planned to include the development and test of experimental job aid materials and devices as well as research on effective presentation techniques for use in printed guides and in film aids and other devices. Unfortunately, what was to have been a three to four year research and development program had to be terminated in less than two years because of curtailments in manpower and funds. Hence, many of the various aspects of the research could not be carried through to fruition at that time (24).

The Air Force interest in job performance aids was again expressed during the early 1960's with the publication of a series of reports by Folley et al (17, 18, 19, 20) under contract to the Behavioral Sciences Laboratory of the Air Force Systems Command. These reports reviewed previous military experience in performance aids, identified research problem areas, and described the development and tryout of a preliminary procedure for systematic job aid design. The Behavioral Sciences Laboratory continues to sponsor research directed toward achieving a better understanding of the many variables which influence the effectiveness of performance aids in maintaining electronic equipment. Among the variables being studied are level of information detail, information format, data flow relationships, and personnel aptitude (16, 50).

Two other research and development programs of the Air Force have definite implications for job aids. Currently underway is a project under the sponsorship of the Air Force Systems Command entitled Presentation of Information for Maintenance and Operations (PIMO) directed toward improving system maintenance by providing a better system for presenting maintenance information to the technician. Specifically, the program is concerned with identifying what information is actually required by maintenance personnel, determing the best way of compiling such information, and optimizing the means of presentation of information to the user.

Specifications for the development of an audiovisual presentation device have resulted, based upon a feasibility study using a helicopter as the test system (37, p. 128-137).

Also related to the area of job performance aids is the program of research under the direction of the Decision Sciences Laboratory of the Air Force Electronics Division (6, 7, 15, 44, 45). The major objective of these experiments is to develop design principles for automated training subsystems which could be incorporated into the design of future information systems.

Reported Effects of Performance Aids in the Air Force Environment

The research effort outlined in the previous section covered a wide range of problems and encompassed studies dealing with the effectiveness of improved job performance aids as well as research into various factors involved in the design of these aids. This section will attempt to summarize briefly the reported effects of introducing performance aids into specific Air Force maintenance situations.

Berkshire's study (5) involved the development and preliminary evaluation of a set of troubleshooting materials for a portion of a radar set. These materials were intended to be explicit and detailed enough such that the mechanic would not need a complete understanding of the functional relationships among the parts of the equipment. Twenty-four trained mechanics participated in the preliminary field evaluation of the materials. Eighteen of the men had a range of experience from seven to thirty-one months with a mean of twenty-one months; while six of the men had little or no maintenance experience. Six different malfunctions were studied and each mechanic had the task of locating two malfunctions. The technician used his own methods for locating one malfunction and for the other employed the specially designed troubleshooting materials.

The experienced mechanics using their own methods frequently lost time through removal of the wrong components. The troubleshooting materials were estimated to save on the average of two hours per malfunction (with time scores corrected to include component replacement and checking time) when used by trained and experienced mechanics. Use of the written instructions, called trouble locators, greatly reduced the errors made by both experienced and inexperienced personnel. Technicians who had just completed maintenance training but who had no on-the-job experience solved the troubleshooting problems in about the same time as the more experienced subjects when they both used the trouble locators.

Two additional Air Force studies provide further information on the extent to which improved job performance aids can compensate for training and experience. Folley and Munger (19, p. 28-29) describe an unpublished study by Hoehn and Aukes which tested the effectiveness of a troubleshooting guide consisting of procedural instructions for locating malfunctions in a simple electrical system. The major findings indicate that troubleshooting ability of untrained and partly trained men can be increased by procedural instructions. The gain appears to outweigh most of the three months of training in electrical principles and general troubleshooting practices. Folley and Munger (19, p. 7) also describe a study of Hoehn and Wardell which indicated that Air Force technicians with a median of seven months experience did as well as technicians with a median of 21 months experience when both used an experimental troubleshooting guide. The less experienced technicians using the guide employed more efficient procedures than did the experienced technicians who were using conventional manufacturer's manuals.

In the PIMO study cited in the previous section, definitive results have not yet been reported. Nevertheless, preliminary findings based upon the employment of a prototype audiovisual presentation aid suggest that such a device, along with reformatted data, can compensate for training deficiencies. It is expected that a maintenance information presentation system will provide increased aircraft availability and significant long term cost savings (37).

The exploratory research into basic problems of automating training for future information systems was aimed at the eventual development of alternatives to the high cost of training operators for computer-based systems. Among the techniques studied was that of display technique, i. e. , taped lectures and slides versus instructional manuals. One experiment using an abstract hardware model of a representative Air Force information system task demonstrated that a taped lecture with logic flow diagrams on slides projected directly onto the control panel of a console could serve as a performance aid or teaching program. When the same logic diagrams were employed in an instructional manual to supplement the text, training time was longer than with the tape/slide program (7).

ARMY RESEARCH AND APPLICATION

Like the Air Force, the Army has been concerned with improving the efficiency of maintenance personnel performance. Hence, much of its efforts related to job performance aids has been directed toward developing improved maintenance support data. Two major programs in recent years were carried out by the Human Resources Research Office (HumRRO) operating under contract with the Department of the Army. Task MAINTRAIN included research on the development of a maintenance manual designed to permit trained technicians to troubleshoot complex electronic equipment faster and more accurately (43). An experimental manual covering troubleshooting the Nike Ajax missile system and its test equipment was evaluated by means of an objective test using two groups of inexperienced technicians to locate malfunctions in the system. The experimental group using the improved manual accomplished troubleshooting substantially faster and more effectively than did the control group which used standard schematic and functional diagrams.

The HumRRO research under task FORECAST involved a variety of related efforts including the development of new training content and improved training methods coupled with improved job methods, aids, devices, and data formats. Conclusions were drawn concerning the total FORECAST approach rather than the effectiveness of individual aids. Major products of the FORECAST approach are a series of troubleshooting guides used for isolating system malfunctions based upon signal flow information. The job aids enable the repairman to do his own thinking, while still benefiting from the deductions made by experienced systems analysts who have previously structured the system in the optimum manner for troubleshooting. Results of the studies suggest that the FORECAST approach can produce technicians in less training time than that required with conventional techniques (46).

The Army Missile Test and Evaluation Directorate conducted a study of the relative effectiveness of an experimental Audio-Visual Information System (A-VIS) when compared to standard technical manuals as a maintenance job aid (52). The A-VIS machine evaluated was an experimental device containing schematics, block diagrams and printed instructions on film chips. The experimental model contained 10,240 film chips plus 80 hours of audio instruction stored on magnetic tape. Selection of a film chip is initiated by punching out a code number on a four column push-button selector. Visual information is displayed on two screens which can be used concurrently or independently. Audio information is also accessed by use of the control console utilizing an eleven-bit code on the film chip.

The study also evaluated four other modes of presenting maintenance information: audio information system (AIS) which involved the audio portion of A-VIS, while the video portion was presented in book form; visual information system (VIS), in which the video portion of A-VIS was used while the A-VIS aural instructions were presented in book form; programmed technical manuals (PTM), in which all of the A-VIS information was presented in book form; and finally technical manuals which included advance copies of engineering drawings and manuals as substitutions for standard technical manuals.

Based on maintenance performance on a group of test problems, it was concluded that A-VIS was superior to technical manuals as a maintenance aid. The major contribution to audiovisual superiority was in information format. All data programmed modes (AVIS, VIS, AIS, and PTM) were superior to technical manuals. While the contribution made by an automatic video retrieval system was significant and enhanced the value of the programs, in no case did the use of an automated audio retrieval system improve the capability of the program. In fact, there was evidence that the audio actually degraded the A-VIS and the AIS modes. The most effective mode tested was the visual information system, while the least effective was the technical manual mode.

The Army, on contract to HumRRO, has also explored the needs for managerial personnel aids that would be useful for junior officer performance and learning (1). Based on a survey and discussion with Army officers, 13 job areas and 34 specific job functions were identified where performance aids would be useful for minimizing the amount and difficulty of the job content that must be learned by an inexperienced officer. A suggested format for a handbook was developed covering what the inexperienced unit officer needs to know about operational and system checks of electronic equipment. It was concluded that, while existing manuals and directives provide helpful guidance, job aids in easily readable form are needed by the inexperienced officer who is expected to perform in a short time. These aids should enable quick and easy access at the job location and should emphasize essential knowledge and skills required early in the job.

Another type of managerial performance aid, nomograms, have been developed by the Army Personnel Research Office for use in evaluating manpower policy alternatives (35). The nomograms facilitate the evaluation of alternative rotation policies by showing the steady-state relationship between personnel allocation percentages overseas and in the U. S. for various tour lengths and selected assignment policy alternatives. Using the charts, management personnel can develop estimates of the effects of a given policy alternative without using a computer and without the need for complex mathematical formulations.

NAVY RESEARCH AND APPLICATION

The Navy in recent years has sponsored several studies which bear directly upon the content of the present report. In 1964, a laboratory model of a head-worn film strip viewer together with audio tape was evaluated as a vehicle for presenting programmed guidance in maintenance task performance (9). The head-worn device is a light-weight unit holding a 35 mm film strip of up to 75 frames. In use, the wearer's environment is visible to both eyes, while a virtual image of the film is presented to one eye using a semi-transparent mirror. Attending to one image or the other is accomplished by focusing the eyes on either an environmental object or the plane of the virtual image. The device was used in the laboratory to appraise its capability in relation to certain display and environmental variables. In addition, it was compared with a larger audiovisual device the effectiveness of which had been previously established.

It was concluded that the head-worn device was usable under a wide range of viewing conditions. When the two audiovisual devices were compared as aids to aligning radar display equipment, they were found not to differ significantly in terms of alignment times. The head-worn device was preferred by six of the twelve participants in the study, with four preferring the comparison device and two expressing a preference for maintenance manuals. The results appeared to support the feasibility of the head-worn device for guiding the performance of specific tasks where there is insufficient space for larger displays and where operator mobility is required during the use of the job aid. However, a number of specific difficulties were identified in using the device which should be corrected in future models prior to further evaluation.

An experimental locator for use in troubleshooting a radio transceiver was developed and evaluated by Rigney and associates (40, 41). The fault locator is a small, circular, plastic job aid incorporating circuit-front panel relationships necessary for fault localization. The aid was designed to be used in checking out the receive and transmit modes of the equipment along with a number of sub-functions.

The technician notes symptoms of malfunction during the checkout, enters these symptoms on the aid, and looks up the indicated malfunctions in an accompanying manual.

In one study (40), 20 radiomen after a three hour training session were given six troubleshooting problems to solve. The results showed that personnel who are relatively untrained in electronics maintenance could learn to use the job aid in a very short period of time and perform specific maintenance tasks such as fault localization that have been recognized as giving highly experienced electronics technicians considerable difficulty. The success of the trouble locator appears to be due primarily to the fact that it presents a well structured and standardized approach to symptom recognition and fault localization. The authors point out that the job aid opens the way for non-maintenance personnel to share a part of the maintenance work load and thereby relieve the over burdened electronics technician.

The fault locator was also evaluated on 30 electronics technicians divided into one experimental group and two control groups (41). One group was given three hours special instruction in the operation of the radio transceiver and the use of the fault locator. A second group was given three hours of instruction in the radio transceiver, but was not given any instruction regarding the fault locator; while a third group was given no special instructions regarding either the radio transceiver or the fault locator. All of the elctronics technicians were given the task of isolating malfunctions to a faulty component. The first group, the experimental group, had to use the fault locator to localize the problem; while the two control groups did not have use of the job aid. The results of the study showed that electronics technicians could learn to use the job aid in the three hour training program and could benefit from its use. While part of the success of the experimental group can be attributed to the special training in the operation and recognition of symptoms of the radio transceiver; nevertheless, the results of both this study and the previous study demonstrate the effectiveness of the fault locator as a maintenance job aid. It appears that both radiomen, who are relatively untrained in electronics maintenance, and electronics technicians can be taught to use the fault locator in a very short period of time and can both benefit from its use.

In a similar vein, Hooprich and Steinemann (25) conducted an experiment to determine if a wallet-sized conversion chart would be a practical and convenient job aid for electronics technicians in performing measurement conversions. Three groups of Navy personnel served as subjects: 42 experienced technicians, 30 trainees from an experimental electronics technician school, and 30 personnel with little or no electronics training. The criterion used to evaluate the job aid was a measurement conversion test. One-half of each group was allowed to use the conversion chart while taking the test, and the other half was not permitted to use any aid. The results indicate that, within the non-technncal and trainee groups, those subjects using the conversion chart did significantly better than those not using any conversion aid. Of particular importance is the fact that both of the trainee groups using the conversion chart did as well on the criterion test as experienced technicians. Questionnaire responses indicate that the subjects considered the conversion chart to be of value in the job or training situation after only brief instruction and practice. Requests by the experienced technicians to retain copies of the conversion chart suggest a positive attitude toward the job aid and justify the belief that it would be useful for certain kinds of technical work.

The Army FORECAST approach described previously was also applied and tested in the Navy environment (47). Following a FORECAST analysis of the Long Range Navigation (LORAN) System, a technical manual and training program were developed containing the major FORECAST products described previously. The graduates of the FORECAST training program were compared with graduates of conventional LORAN maintenance courses on their ability to find malfunctioning parts in the equipment. The graduates of the FORECAST program identified approximately three times as many malfunctioning parts as did the graduates of conventional training.

CIVILIAN RESEARCH AND APPLICATION

As pointed out earlier, the articles in the technical journals and trade publications generally speaking consist of individual reports of experiences in developing or using specific job aid devices. A number of reports were authored by representatives of organizations associated with the development and sale of such a device. Reports of research findings of the type discussed in the previous section are almost totally absent from the generally available civilian literature. Nevertheless, in order to provide a complete picture it is worthwhile to identify and review the reported experiences of job performance aids in industry.

The literature reflecting industrial experience has been concentrated in the areas of assembly and inspection. The remainder of the relevant reports identified have been grouped together and will be discussed in the final portion of this section.

Job Performance Aid Research on Inspection Tasks

The major industrial research on job performance aids identified during the course of the present study was conducted by Teel and his associates. Unfortunately, the research does not appear to be reported widely, but rather is contained primarily in company publications. Teel, however, did report to the 1966 meeting of the American Psychological Association on a study conducted with Chaney (48). A four-hour training program and a set of visual aids were desiged to overcome deficiencies in the performance of machined parts inspectors. Effectiveness of the two approaches was evaluated singly and in combination, using three experimental groups and a control group. The criterion used was the percentage of true defects detected in a selected sample of machined parts. It was found that use of either training or visual aids resulted in large gains in the detection of objective defects; but the combination of training and visual aids resulted in the greatest improvement. Specifically, the use of training alone resulted in a 32% increase in objective defects detected; use of visual aids alone resulted in a 42% increase; and the combination of training and visual aids resulted in a 72% increase; while the control group performance did not change.

The improvements resulting from separate application of the two approaches, training and visual job performance aids, were not significantly different in terms of overall objective detection performance. The visual aids, however, were twice as effective as training in improving the detection of mislocated holes. These findings suggest that the relative effectiveness of the two approaches is dependent on the specific types of defects being inspected.

The visual job aids studied by Teel and Chaney consisted of a series of simplified drawings. Dimensions, tolerances, and inspection criteria for the characteristics inspected were located on the drawings to reduce the need for calculations and reference to other materials. Similar items were grouped together on individual pages in order to focus the inspector's attention on one type of defect at a time. Characteristics that were not to be inspected were omitted from the page.

It was concluded that for maximum inspection accuracy both training and visual aids should be developed. According to the authors, whether to use training and/or visual aids for any specific application should be based upon a determination of the cost-effectiveness of the two methods.

Several unpublished studies by this group also merit discussion (26). Harris conducted two studies evaluating the effectiveness of photographs as job aids for inspecting solder joints. In the first study, photographic inspection aids for use in inspection of solder joints were developed and evaluated. A comparison was made of the performance of a group of 18 inspectors when inspecting solder joints with and without the aids. It was concluded that the use of the job aids significantly increased the agreement among the inspectors on the acceptability or unacceptability of the solder joints. Use of the photographic aids resulted in a significant decrease in the percentage of good solder joints rejected but no significant change in percentage of bad joints accepted. Because of the success of the visual aids in improving one of the most difficult of inspection areas, Harris suggests that photographic aids would likely improve the performance in other kinds of inspection.

In a related effort, Harris studied various characteristics of photographs for their value in communicating inspection standards to inspectors. Eight sets of photographs were developed, one set for each combination of characteristics. A group of 24 inspectors inspected solder connections, first without using photographs and then using certain combinations of the photographs. The results indicated that use of the photographs significantly reduced decision and diagnostic errors and increased decision and diagnostic agreement. Black and white photographs were found to be as effective as color photographs in inspecting the solder connections. Also, 4 x 5 inch photographs were found to be as effective as those 8 x 10 inches in size. The results further indicated that photographs of examples near each side of the acceptable/unacceptable borderline were more effective than photographs of examples far removed from the borderline.

In another study, Sadler evaluated an overlay inspection aid designed for use in visual inspection of the photographic masks used in the production of circuit boards. Thirty subjects inspected a sample of these photo masks containing a variety of defects. Half the subjects used the job aid, while the remainder inspected without it. Use of the overlay inspection aid resulted in significant improvements in the detection of two of the three types of photo mask defects studied. Sadler concluded that the overlay technique provided a significant improvement over current procedures and recommended that it be adopted for use in photo mask inspection.

Job Performance Aid Usage in Assembly and Inspection

A total of seven articles covering the merits of audiovisual presentations as electronics assembly job aids were identified during the review of trade publications and technical journals (2, 3, 11, 21, 23, 27, 42). The articles were all published during the period between 1960 and 1963. These reports described the experiences of companies in applying the tape/slide type of performance aid.

The basic components of this audiovisual display include a 35 mm slide projector with self-contained screen and a two-channel magnetic tape recorder with earphone attachment. The components are mounted in a display case which resembles a portable TV unit. The display is equipped with front panel control knobs, buttons, and loading; positioned for convenient use by the operator. The programmed script (on one channel of the tape) and color slides are synchronized through a step-by-step process to provide the worker with the specific instruction and slide at the moment required. The sequencing of slide and script is accomplished by inserting a pulse code on one channel of the tape which triggers the projector at the appropriate time. The A-V "package" can be operated either automatically or switched to manual operation at the discretion of the operator.

Variations to the basic display provide added convenience or capability. For instance, a foot pedal or switch may be added to interrupt the automatic sequence or to trigger viewer-tape playback. A projector capable of projecting pictures on a larger external screen as well as the built-in screen may be used to more clearly illustrate complex wiring. Music may be inserted on the tape during the time between completion of instruction and completion of the process. Simplification is also offered by the A-V system in that it is possible to use only one of the two basic components, the slides or the tape.

The claims made in these seven articles do not appear to be based upon controlled research studies. In any event, the absence of supporting information explaining how the data were derived precludes anything approaching an adequate evaluation of the information. Of the seven articles, four dealt primarily, if not completely, with the experiences of the company which developed the original tape/slide device for its own use and later became the major producer of the AV unit for industrial use. The remaining three articles cited the use of the audiovisual units in six other companies and presented the results in more or less detail from four of the organizations.

Despite the obvious deficiencies in the information covered in this section, it is felt that the report would not be complete without an attempt to summarize the reported information. Accordingly, Table 2 presents a summary of the specific claims for the five organizations covered in depth in the seven articles. While it must be emphasized that the figures in the table should be interpreted with caution, the nature of the specific reported advantages merits discussion. As indicated in the table, one or more of the organizations claimed sizeable reductions in five specific areas:

- Learning time
- Number of defects
- Supervisory time
- Inspection time
- Assembly time

The specific savings claims were accompanied by a number of supporting statements of perceived gains. Among these supporting claims are:

1. Standard procedures developed and corrected.
2. Paced instructions give operator a specific target for performance.
3. Allows operator to proceed at own pace.
4. Increased capability to perform complex work.
5. Eliminated need for close scrutiny, coaching, and guidance by instructor for complicated tasks.
6. Increased worker versatility.
7. More uniform product quality.
8. Improved product quality.
9. Inspectors using AV program aid consistently inspected to the same criteria.
10. Supervision freed of instruction duties, more time for managerial responsibilities.
11. Employee acceptance due to reduction in decision making and increased assurance of satisfactory performance.
12. Employee appreciation of solitude and elimination of distracting sounds when using earphones.

TABLE 2

SUMMARY OF CLAIMS REPORTED FOR AUDIOVISUAL PERFORMANCE AIDS*

Reported Advantages	Company Designation				
	A	B	C	D	E
Reduction in learning time	80%	50%	50%		45%
Reduction in defects		60% 90%		85%	49%
Reduction in supervisory time			80%	70%	
Reduction in inspection time				85%	50%
Reduction in assembly time		64%			50%

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* Based on review of trade journal articles (Bibliography items 2, 3, 11, 21, 23, 27, 42)

On the other hand, a few precautionary statements and possible disadvantages were contained in the seven articles. In this category were the following comments:

1. Technique best applied when work was complex, time consuming and critical in regard to assembly steps and quality of workmanship.
2. Resentment toward rote process from particularly skilled operator.
3. Inexperience in using system can lead to trouble.
4. High engineering change rates, small quantity production, and simple or repetitive assembly steps limit value of AV programming.

Application of Job Performance Aids in the Scientific and Engineering Work Areas

Even a casual review of the technical publications today reveals the wide-scale impact that the computer is exerting upon the nature and content of technical work areas. While in many cases still in the promissory stage, development of computer-based job aid display systems will very likely play a major role in influencing the informational requirements of many technical jobs. Although a thorough analysis of the computer and related instrumentation goes beyond the scope of the present study, a few of the highlights can be presented. For a discussion of the overall R&D instrumentation area and its effects upon the management of professional and technical personnel, see Bronson's recent article (8).

Advances in the field of man-computer interaction are being developed so swiftly that very few of the accomplishments have been described in the general literature. For the most part they are being reported in the limited distribution reports of various governmental, university, and industrial laboratories. One of the latest reports on the potential of computers for extending man's problem-solving capabilities was provided by Newman (34). In reviewing the implications of computer-based information processing and display systems, he predicts that on-line computer systems will play a major role in the upcoming emphasis upon improving high-level human performance in executive planning and decision making. He suggests that we are a long way from determining the upper limit of man's intellectual ability for problem solving. According to Newman, by concentrating on providing computer and display aids and extending his ability to manipulate data, man's problem solving and decision making abilities can be increased tremendously.

There is a second category of reports in the technical and trade publications that bears very directly upon the job performance aid field. These reports deal with the development and application of individual aids such as conversion charts, calculating tables, nomographs, special purpose slide rules, etc. The number of new aids being developed and reported on and/or marketed is frankly amazing. These aids cover a myriad of applications, and are primarily designed to eliminate the need for performing mathematical calculations in order to arrive at solutions to such problems as unit conversion, material requirements estimation, machine speed and feed calculations, and the like.

Reflecting the growing activity in the field is an article by Kravitz (29) which suggests that when faced with frequent use of a few selected formulas, it may pay to design and build ones own special slide rule. The author indicates that, with such a job aid, much of the repetitive calculations can be avoided and more rapid answers developed by personnel with lesser mathematical ability.

With similar objectives, Baum reported on the uses of nomography in a research laboratory (4). Among the advantages claimed for nomographs are:

- Expedites routine calculations. Saves time and tedious effort.
- Permits technical assistants to carry out computations whose bases are beyond their mathematical skills. Eliminates formulas and the need to look up values in tables.

In Baum's opinion, only eighth grade arithmetic is needed for using nomographs, in contrast to college level mathematics otherwise required. Because of the many benefits of nomograph usage, Baum urges that consideration be given to including nomography in the engineering curriculum. Whitehead (54) agrees with Baum on the usefulness of nomographs for engineers. He describes a simple procedure for constructing a nomograph.

Finally, the development of an audio job aid for flight control system checkout and troubleshooting was reported in a trade journal in 1964 (14). The device consists of a specially designed magnetic tape player and handheld control. A prerecorded tape contains a series of detailed troubleshooting instructions on one track, while another track contains the troubleshooting logic sequence in digital form. Depending upon the results of each test item, the tape automatically proceeds in logical sequence until, according to the article, the malfunction is detected. The tape also refers the technician to a specific page in an accompanying manual which shows interconnecting wires, replacement procedures, and other information required. It is claimed that through the use of this device less skilled personnel can troubleshoot the system successfully. At the time of the article an evaluation of the aid was reportedly being conducted. Recent correspondence with the manufacturer indicates that the device was not successful in its original application due to the following reasons: a large number of modifications in the complex new flight control system, resulting in great difficulty keeping the tapes up to date; problems with unreliability of the job aid devices initially supplied by a subcontractor; and labor jurisdictional problems as the job aid was intended to be used by less skilled personnel to perform maintenance tasks which the skilled tradesmen successfully argued they should perform. The device is still being evaluated on a very limited basis in a military environment. While the company that developed the system has faith in its potential, it has decided against further exploitation of the equipment due to slow development of its potential applications and the pressures of more urgent and profitable work.

Electronics Survey

FIELD SURVEY OF PERFORMANCE AID UTILIZATION IN ELECTRONICS ORGANIZATIONS

SURVEY METHODOLOGY

Data Gathering Format

Basic data covering the types of job performance aids being employed in the electronic assembly field were obtained through interviews with plant personnel and by direct observation of assembly/fabrication areas.

Development and validation of the basic data gathering forms and general content of questions to be asked during in-plant interviews were accomplished within the Philco-Ford Western Development Laboratories (WDL) facility prior to initiating the field survey. Several combinations of forms and methods of interviewing were tried out in a number of WDL fabrication departments with the following results:

a. Attempts to structure the investigation with gross task descriptions as core material proved to be too time consuming and restrictive for the level of information desired. The major deficiency in this approach was that many tasks associated with a given work area might not be covered during the interview if specific types of assembly operations had not been performed recently.

b. Employment of an entirely open-ended, relatively unstructured interview also proved to be unsatisfactory in that significant blocks of information were often omitted and had to be obtained with follow-up contacts. This approach also presented problems in maintaining a central focus on job performance aids rather than on production methods, materials, etc.

c. A general outline of interview content that did not require a rigid sequence of questions and answers proved to be the most efficient and comfortable technique to follow. The data gathering format decided upon served as a frame of reference for guiding the interview and was not intended to cover all the details of the entire interview. In keeping with the exploratory nature of the survey, the items on the form served as the stimulus for a variety of additional questions during the lengthy interview and observation. A copy of the interview guide employed is included as Appendix D.

Selection of Companies

A total of twelve industrial facilities were included in the field survey. Because of the exploratory nature of the study and the limited scope of the field survey, no attempt was made to secure a representative sampling of a specified population. Rather, the selection of firms was made on the basis of expected yield of practical information. Specific considerations in the selection of plants to be surveyed were as follows:

Size of facility. An attempt was made to obtain as wide a range as possible within the primary geographical area of the survey. The number of employees directly involved with assembly tasks ranged from 50 to 1500. Estimated overall organization size ranged between 400 and 15,000 employees.

Geographical location. The majority of facilities contacted are located in the San Francisco Bay Area bordered by San Francisco on the Northwest, Oakland on the Northeast, Santa Cruz on the Southwest and San Jose on the Southeast. This area covers approximately 1200 square miles and represents a population of over two million. Of the twelve facilities included in the study, eleven are located in the Bay Area and one in Los Angeles.

Type of manufacturer. Manufacturing processes include assembly of components on printed circuit (PC) boards, assembly of completed PC boards into sub-assemblies and, in turn, into final assemblies. These final assemblies varied from electronic desk calculators to complete missile and space vehicle communication and control systems. Production processes covered by the survey included: soldering solid state components on PC boards; construction of wiring harnesses for boards that contained as many as 8,000 separate wires; and manufacture of integrated circuits (IC), also referred to as chips or dies.

Experience with audiovisual aids. A number of firms were included in the survey because they had, at one time or another, employed various types of audiovisual devices for direct application to the assembly process. These applications involved the development of programmed procedures covering assembly tasks for a given work station.

Job skills. The coverage of job skills paralleled that of manufacturing processes in that the number of basic skills increased with the number of, and diversity of, manufacturing processes covered in the sample. Basic skills and knowledges found during the survey were: soldering, wiring, manipulation of various microdevices employed in the manufacture and assembly of IC chips, inspection, and attachment of IC terminals to external electronic leads.

Data Collection Procedures

Personnel or industrial relations departments of firms selected for the survey were contacted initially by phone. The nature and purpose of the study was explained and a referral was requested to the department or organization most closely associated with production or in-plant training areas.

The next contact was with production or training personnel. The nature of the study was explained in detail and an appointment was requested for direct interview and tour of electronic production areas. All requests for referrals were granted.

Access was denied to the production areas of only two micrologic firms because of plant security policies invoked to preserve proprietary manufacturing processes. Personnel contacted were highly cooperative in all phases of the investigation and provided more information and assistance than originally requested.

The data collection method usually employed was to conduct the interview with two investigators; the first asking questions and engaging in the majority of conversation, while the second recorded significant details. Interviews averaged two hours in length with an additional hour being devoted to a tour of production areas. Recorded notes were later transcribed, following a standard report format. Follow-up contacts by phone to verify information previously obtained, or to secure additional information, were made in a number of instances.

SUMMARY OF SELECTION AND TRAINING PRACTICES

Selection

The plants covered by the survey, with only two exceptions, have selected and trained inexperienced personnel for electronic assembly positions. Common selection criteria are 10th grade education, normal color perception and average scores on some form of motor coordination, clerical perception, and form perception tests.

Training

Pre-employment training. Applicants meeting the general requirements must in most cases successfully complete a company sponsored 40 hour classroom training course as a pre-condition of employment. These courses cover soldering techniques (or micro production techniques), electronic component nomenclature, understanding engineering drawings, and general familiarization with assembly techniques. At least 50% of the standard one week training course for entry level assemblers is devoted to acquisition of basic manipulative skills required for soldering or harness construction and parts handling techniques. The remainder of classroom time is devoted to familiarization of the trainee with parts nomenclature, production drawings, and basic job performance aids. Applicants are typically not paid while in training status and are not guaranteed employment upon successful completion of the company sponsored course. The dropout/failure rate for these courses has been reported as being relatively small by firms covered in this survey.

Post employment on-the-job training. Personnel successfuly completing the pre-employment training courses are hired by the sponsoring firms with few exceptions. Newly hired personnel are placed at an assembly station on the first day of employment and are expected to perform standard assembly tasks. A foreman or experienced worker usually conducts informal on-the-job training (OJT) on an as-required basis until the new worker is considered to be proficient.

None of the firms contacted had maintained historical data that would indicate statistically derived learning curves for new employees. According to supervisory and staff personnel, from two to five days are required to fully meet production standards for the simplest assembly tasks.

JOB PERFORMANCE AIDS USED IN ELECTRONICS ASSEMBLY

Overview

Several types of standard job performance aids were found to be in use in each facility contacted. These aids included engineering and special drawings, production prototype models, and photographs of subassemblies and final assemblies in various stages of completion. Such aids are fairly common in industry and have been extensively employed throughout the development of the electronics field.

Other types of aids such as audiovisual devices, audio devices and specially designed templates or overlays have also been applied to the manufacturing or assembly process. Results of the field survey reflecting the use of these various types of aids are given in Table 3. Unfortunately, objective data documenting the specific effects of job aids were generally not developed or were otherwise unobtainable during the survey. This was particularly the case with the more standard job aids

TABLE 3

FIELD SURVEY OF ELECTRONICS ASSEMBLY

FIRM	AV JPA		AUDIO JPA		Engineering Drawing	SPECIAL PRODUCTION AIDS			
	Installed	Continued Use	Installed	Continued Use		Drawings	Photos	Models	Overlays
A					X			X	
B					X			X	
C	X	X	X	X	X				X
D	X	X			X	X	X	X	
E					X	X	X	X	
F	X				X	X	X	X	
G	X		X	X	X	X	X	X	X
H	X	X			X				
I	X				X			X	
J			X	X	X				
K					X	X	X	X	X
L	X	X			X	X	X	X	

that have been in existence so long they are considered to be an intrinsic part of the job and their effectiveness is seldom, if ever, questioned.

Visual Job Performance Aids

It can be seen from Table 3 that the use of engineering drawings is universal within the sample studied and that employment of three dimensional models is fairly extensive. The engineering drawing must of necessity be employed during some phases of the manufacturing process since it is the official document or standard covering the component or assembly being produced. This type of job aid includes drawings of one or more views of the items being produced, accompanied by assembly instructions and lists of materials.

The use of photographs, models, or specially prepared drawings normally served as augmentation material to the engineering drawings. These additional aids were usually developed when basic engineering drawings were found to be inadequate with respect to simplicity or degree of detail required for production purposes. The use of photos, models, or special drawings varied within a plant from production run to production run; their use being dependent upon such factors as complexity of assembly, type of assembly technique, required number of items being produced, and number of components or electrical connections required to be installed at an assembly station.

The determination to use models or photos was usually made by industrial engineering or training personnel during the development process for a given production run. In several cases, models or photos were developed to alleviate excessive human error or reduce production time at given work stations. Several firms followed a standard practice of producing special drawings and assembly instructions for all assembly operations. They employed the general format of simplified, step-by-step instructions used by several manufacturers of "do-it-yourself" electronic component assembly kits.

Overlays developed by two of the companies have proved to be quite successful in the assembly of printed circuit cards containing a large number of solid state components. The arrangement of component bins has been integrated with the use of overlays to virtually eliminate operator decision in selecting or locating components to be attached to the printed card. One firm indicated that production efficiency has been "significantly increased" and that assembly error has been reduced to near zero. Use of the overlay devices also materially reduced familiarization time for workers newly assigned to printed circuit assembly stations.

Audiovisual Job Performance Aids

These types of aids have been used far less frequently than the types previously mentioned. Instructions for such devices are similar to that used in the special drawings and simplified instructions of the "do-it-yourself" electronics kits previously discussed. Advantages of this system reported in the trade literature are that workers have continuous use of both hands through use of foot pedal controls and are provided with complete assembly instructions via the audio and video channels. A description of the audiovisual job aid was presented earlier in the report in the section discussing industrial job aid literature.

Use of these devices as on-line performance aids accelerated rapidly during 1960 and 1961. In seven of the twelve firms surveyed, approximately 80 units were in use during the peak period of 1962. In general, they were withdrawn from the production area at nearly the same speed as their original installation. By 1963 very few remained in full time service as on-line aids. This extremely rapid acceptance of AV units reflected the pressure for quick answers regardless of the lack of objective evidence. The need for careful planning and the importance of high quality audiovisual programs was either not recognized or was disregarded in the frantic rush. Moreover, the expectations of the amount of gains and the speed with which the gains would be realized may have been unrealistic.

Out of a total of seven firms originally installing AV devices during the period from 1959 through 1962, four have continued their use in one form or another, according to the field survey data. None of these devices was employed continuously for any extensive time period (a maximum of 6 months) as on-line procedural support aids. The reason stated for this short term use by several firms was that employees rapidly learned content and in most instances did not have to rely upon either the audio or visual portion after 5 or 6 trials. The period of time that a worker would have to rely on such information would naturally be dependent upon the length and complexity of the assembly process and worker retention capability.

One of the firms no longer using AV devices reported that audiovisual programs were initially developed during the early 1960's for assembly of standard printed circuit cards that had been in production for some time. The devices were discontinued when production records failed to indicate gains in output or product quality. Printed circuit cards assembled with the AV job instruction process required an average of 30 minutes to complete and contained approximately 20 to 30 components. Considering the short cycle time and the number of components placed on the PC boards, such tasks would be classified as simple assembly tasks by contemporary standards.

Applications of AV devices to relatively simple, short cycle, assembly tasks with little or no gain in output per unit time was cited as one of the primary causes for discontinuing AV equipment as on-line job performance aids by other firms in the sample. Several firms also cited lengthy time lags and excessive costs required to re-program AV material to reflect changes in production methods and components.

Several individuals who were directly involved with development of audio scripts and production of slides for the early applications indicated that their initial efforts were somewhat clumsy and that lack of "professional" programming also could have contributed to the disappointing showing of certain production line applications. Data that would have reflected the relative impact in terms of increased productivity or quality were not collected during this period, at least in any consistent fashion. It might have been impossible to determine the effect of AV or similar devices at the time even if data were collected because of the many variables operating in the production environment.

The four firms continuing to use AV systems report that the devices are primarily used as storage libraries of assembly instructions for infrequently produced equipment that requires unique assembly practices and techniques. Employment of the devices in this manner eliminates the requirement for costly retraining of personnel in preparation for production. Also reduced are rejections and re-work rates that are typically highest during the early phase of a production run.

One firm also uses AV systems to maintain desired levels of skills and production practices for areas requiring high quality control standards. Programs covering basic techniques of potting or application of gold foil, for example, are periodically presented to workers in the production area. Direct relationships between presentation of material and subsequent improvement of production quality is claimed for this application.

Audio Job Performance Aid Devices

Employment of audio job performance aids in the electronics industry has been relatively recent. The three firms indicated in Table 3 as using these devices have installed them within the last two years and are still in the process of experimenting with the technique. In all cases, audio job aids have been programmed for cable harness or cable board wiring that by its nature cannot be simplified or reduced in complexity. Use of audio has proved to be highly successful in this application. Programmed audio instructions on tape at one plant reduced assembly time from an average of 17 hours to approximately 2-1/2 hours. Reduction in wiring error was also noticed, although specific data were not available.

Taped instructions at a second plant covering a very lengthy and complex rewiring of switchboard units have resulted in a 50% reduction in labor hours for wiring tasks. Along with labor hour reduction, errors averaging six per job have been reduced to two. Additional manhour and cost savings were effected by the elimination of troubleshooting time induced by wiring errors. A further advantage attributed to the audio system was that an inexperienced worker with only basic skills could be placed at the station and immediately begin wiring tasks without special familiarization training.

Audio tape instructions have also been developed at one facility to cover instructions for repair of equipment that is infrequently processed. Use of such instructions has eliminated the requirement for employee familiarization prior to the undertaking of infrequently performed and rather intricate repair or troubleshooting tasks.

Patient Care Survey

FIELD SURVEY OF PATIENT CARE AREA

SURVEY METHODOLOGY

Interviewing Procedures

Data covering the types of job performance aids utilized in patient care were obtained through interviews with hospital personnel and by direct observation of patient care areas. The interview guide employed for the electronic assembly field survey was also used in the patient care area. Again, the basic form was supplemented with additional questions during the course of the interview.

Interviews conducted with hospital personnel were less structured than those conducted for the electronics portion of the survey. However, the method of interviewing using two investigators was generally followed. Notes obtained during the interviews were later transcribed following a standard report format.

Survey Sample

A total of twelve hospitals were included in this portion of the field survey. A number of considerations were made in the selection of hospital contacts. Variables considered were:

Size of facility. The majority of hospitals contacted were relatively large with respect to bed capacity with the exception of two rural hospitals. The bed capacity ranged from a low of 50 to a high of 1200; with the majority of hospitals having from 400 to 600 beds.

Geographical location. Of the twelve hospitals in the survey, nine were located in the San Francisco Bay Area bordered by San Francisco to the North and San Jose to the South. One hospital was located in the greater Los Angeles area; while the two remaining hospitals were situated in smaller communities located approximately 30 to 50 miles to the south of San Jose.

Type of hospital. An attempt was made to select a cross section of hospital sponsorship. Those sampled included university, religious, military, Veterans Administration, Public Health Service, rural community, rural regional, and county. One convalescent home was included in addition to the above.

Job skills. The coverage of specific job and knowledge areas was centered about those positions directly involved with patient care. Most often included were the positions of registered nurse (RN), licensed vocational nurse (LVN), and nursing aide.

Source of information. Interviews were conducted primarily with directors of nursing or with RN in-service instructors. Several contacts were with training representatives of personnel departments and with hospital administrators. Direct observation of patient care areas was made in ten of the twelve facilities.

SELECTION AND TRAINING PRACTICES

Position Responsibilities

The following descriptions of duties and responsibilities summarize the patient care positions included in the survey sample.

Nursing Aide. Under direct supervision of nursing staff, assists in the care of hospital patients by such tasks as: making beds under open, anesthetic, and occupied conditions; answering call bells; serving meals; bathing patients; and taking and recording temperature, pulse, and respiration rates. May apply various hot and cold therapy devices (compresses, packs, pads, etc.) and assist the RN in the routine portions of patient care.

Licensed Vocational Nurse (LVN). Assists in patient care under direction of physicians and professional nurses. Provides wide range of bedside care, as indicated under nursing aide, and assists RN with various therapy procedures. Charts patient's records; applies dressings; operates inhalation therapy and other equipment; performs pre-operative and post-operative care; administers medications with various restrictions. Most commonly, the LVN is permitted to administer previously prepared medications orally and by hypodermic syringe.

The greatest variability in performance of duties and responsibilities was found in the LVN area. Responsibilities and duties were assigned on an individual basis in all hospitals employing LVN's. In-service and supervisory personnel reported wide variances in both training and abilities of LVN's. Much of this was attributed to differences in licensing standards of various states in which licensing was originally granted.

Registered Nurse (RN). The general duty professional nurse provides the full range of nursing care, including administration of treatments and all forms of medication prescribed by physician. Prepares equipment and assists physician during examination and treatment. Observes, records, and reports patient's condition and reaction to drugs and treatment. May perform bedside care functions as described under LVN and nursing aide. May also serve as leader of nursing team composed of RN's, LVN's and nurses aides.

Selection and Training Requirements

Nursing Aides. Selection requirements for entry level nursing aide personnel are typically: "some high school" and good mental and physical health.

Training courses for entry level positions consist of from 50 to 100 hours of classroom training and from 150 to 230 hours of clinical experience (OJT). Total training time ranges from four to eight weeks. Applicants with appropriate experience are given standard orientation training which averaged 40 hours in length.

Licensed Vocational Nurse (LVN). Vocational or practical nurses must be graduates of an instructional program in vocational nursing approved by the State and have passed the licensing examination. Training programs in the area surveyed are approximately one year in length and include both classroom study and clinical practice in basic patient care.

Registered Nurse. Must be registered as a professional nurse by the State of California. In order to be registered, an individual must be graduated from an accredited school of professional nursing approved by the State Board of Nursing Education and pass a State Board Examination; or, if registered in another state, submit evidence of having met equivalent requirements. Professional nursing education programs consist of (a) two year associate degree programs offered by junior colleges, (b) three year diploma programs conducted primarily by hospitals, and (c) four or five year baccalaureate degree programs offered by colleges and universities.

All hospitals provide some form of orientation for newly hired LVN and RN personnel. The time periods devoted to this process range from one to two days for smaller hospitals to eight weeks for one of the government hospitals. The majority of courses are of one to two weeks duration.

In-Service Training of Returning RN's

Several hospitals provide formal retraining for RN's who have not practiced nursing within the past five years. Completion of a refresher course is an employment requisite for five of the hospitals surveyed. These courses last from 9 to 12 weeks and cover basic hospital practices and policies with particular emphasis being placed upon the newer procedures, equipment, and medications. In-service instructors provide the majority of training which normally consists of one-half classroom and one-half clinical practicum. Several instructors stated that this type of training must be handled on an individual basis because of wide variations in experience backgrounds of returnees. Individuals who have not practiced within the past 15 years must absorb a vast amount of information before they can resume basic floor nurse duties.

Recruitment and Turnover

None of the metropolitan hospitals covered in the survey reported any major difficulties with recruitment but indicated that turnover was a chronic problem. Annual turnover rate for combined patient care positions varied from 30 to 150 percent. One hospital reported a yearly turnover of 100 percent for RN personnel.

No significant problems with availability of applicants have been encountered within the past six months. This current condition was attributed by several directors of nursing to recent sizable salary increases granted to all levels of patient care personnel working in the San Francisco Bay Area.

The reverse condition was experienced by the rural hospitals in the sample. Turnover was reported seldom to exceed 20 percent, but recruitment of a sufficient number of RN's for full staffing was a continuing problem.

JOB PERFORMANCE AIDS USED IN PATIENT CARE

Overview

The field survey of job performance aids for the patient care area covered those aids required to support RN's, LVN's, and nurses aides. A number of procedural and reference types of job performance aids were provided to patient care personnel in all hospitals surveyed. These typically included one or more procedures manuals, a standard drug reference, conversion scales, standing orders, and reference textbooks. Generally speaking, these job aids have been developed to support complex or critical tasks, such as preparing medications. Consequently, they are used primarily by professional nurses and, depending upon hospital policy, by LVN's. The interviewing sessions and the limited observation of selected nursing stations were directed toward obtaining information on the types of job aids in existence. Objective records on their frequency of usage and their effect on job performance were not available in the sample of hospitals surveyed, and time did not allow obtaining such data in this exploratory study. However, some indications of the importance of job aids and the frequency of their usage are provided in the following paragraphs.

Procedures Manuals

Every hospital in the survey provided procedures manuals for each nursing station or patient care area. These manuals contain detailed procedures for all facets of patient care from admission through discharge. Organization and arrangement of the manual varied considerably within the sample. Some institutions developed separate volumes for administrative, clerical, and technical procedures; while others arranged all procedures by functional area. Standard size, 3-ring binders and some form of tab indexing was used in nearly all of the manuals.

These manuals are apparently used most heavily by newly assigned or inexperienced RN and LVN personnel; the frequency being dependent upon the degree of supportive supervision given and the amount of time available for study. Several supervisory and in-service training personnel indicated that newly assigned RN's required from 2 to 4 weeks experience on a nursing station to become familiar with "hospital specific" procedures and policies. During this period the manuals were expected to be used frequently. No records were available as to how frequently procedures manuals were used or what effect they had on nursing performance. However, in-service training personnel often expressed concern that such aids were not used as often as they should be.

Drug Reference

One of more standard drug reference books were found at the nursing stations in every hospital surveyed. The most commonly used were a drug formulary and the Physicians Desk Reference (PDR). The drug formulary is a 6x9, tab indexed, loose leaf binder. Formularies varied in thickness from approximately 4 to 7 inches. The PDR is a hard bound, thumb indexed, reference book that is approximately the size of a college standard dictionary.

Both references contain basic information covering generic and trade names, normal dosages, contraindications and side effects for drugs in common usage. The formulary is more detailed than the PDR, containing additional information such as diagrams of molecular structures.

Nursing personnel engaged in direct patient care stated that they used this type of reference from a minimum of once or twice a week to three or four times a shift. All RN personnel queried about use of this type of information stressed its importance and stated without exception that they should refer to these references more often than they do. One of the problems is finding the time to locate the information in the bulky reference volumes. The PDR was preferred to the drug formulary in all instances where both were maintained. The reasons given for the preference being: (1) information access is easier and faster in the PDR; and (2) unnecessary technical information relating to detailed chemical and molecular structure is excluded from the PDR.

Conversion Scales

A wall chart containing conversion values from apothecary to metric systems was found on all nursing stations. This type of chart was used frequently by all personnel who prepared medications.

Other types of wall conversion charts were also found in many of the medicine room or nursing station areas. One of the more common of these is a chart for converting drops per minute to cubic centimeters per hour, for use in connection with administering intravenous solutions.

Many nursing personnel carried pocket conversion scales for personal use. In-service training staffs in several of the hospitals surveyed provided various types of these devices to new personnel. In all cases but one, the conversion scales were distributed by drug manufacturing concerns. The one exception was a government hospital that employed a conversion device of its own design.

Several types of scales and conversions found to be commonly in use were:

a) grain fraction to milligrams,
b) grains to grams,
c) apothecary to metric volume,
d) centigrade to fahrenheit temperatures, and
e) slide rules designed to provide special purpose calculations, such as determining desired rates of flow per unit time.

A number of firms also produced cards containing basic reference information such as common hospital abbreviations, medical symbols, and normal values for blood, urine, and cerebrospinal fluid.

Standing Orders

Standing orders; i.e., procedures to be followed in preparing patients for various laboratory tests and x-ray examinations, were employed in all of the hospitals. These orders were usually printed on 3 x 5 cards and maintained in a central filing box at each nursing station.

Cards covering specific tests scheduled for a patient are removed from the file and attached to the patient's Rand (a universal term in local hospitals referring to a 5 x 8 visible card file system) at the time each test is scheduled. The card serves as an action "flag" and remains on the patient's Rand until all required steps have been completed. A number of hospitals supplemented the standing order "flags" with additional color coded indications that denoted "hold" or "add" actions for special dietary or medication requirements.

Based upon our interview findings, this type of job aid is an integral part of the nursing routine and is universally used whenever patients are scheduled for tests requiring special patient preparation.

Reference Textbooks

Reference material consisting of medical and nursing textbooks and journals were also found at the majority of nursing stations. The availability of this type of material did not appear to be related to the type of patient care area involved, but in most instances reflected personal donations and availability of material from the hospital library. Several random spot checks of nursing information texts revealed publication dates ranging from 1954 to 1966. Frequency of use appeared to be highest in specialty stations such as intensive care and cardiac units.

Discussion & Conclusions

DISCUSSION

PRELIMINARY FRAMEWORK FOR THE FIELD OF JOB PERFORMANCE AIDS

The results of the literature review and the field study, while limited in scope, nevertheless suggest that the area of job performance aids merits greater attention both in terms of conceptual development and in terms of application.

Looking at the many different types and formats of performance aids and the variety of the uses to which they have been applied, it is interesting to speculate upon why greater progress has not been made in developing the field. Perhaps the very pervasiveness of job aids accounts for the lack of a unified conceptual approach. Being surrounded by informational aids of one sort or another, we have failed to recognize that, regardless of their dissimilarity, these aids share common objectives, common functions, and common problems.

In contrast, the area of training has been recognized as a cohesive field and accordingly we see developing over many years a rather rich body of knowledge, basic concepts, and principles. Specialty areas continue to be identified where further knowledge must be obtained. This very structure in turn spawns additional activity which contributes further to the progress in exploiting training as an instrument of manpower utilization.

Unfortunately, the same cannot be said for job performance aids. The major exception to this dearth of job aid research and application is in the area of maintaining complex equipment. Here, because of the critical problems associated with the operational utilization of electronic systems, and due primarily to the foresight of a group of military research and planning personnel, we can trace the progress being made in attempting to improve equipment maintenance through the design of improved informational aids.

An excellent discussion of job performance aids and their role as stimulus control instruments in man-machine systems has been provided by Wulff and Berry (55).

Nevertheless, much remains to be accomplished even in the area of equipment maintenance instructions. Chapanis pointed out this problem recently (10) when he called attention to the language and words associated with tools, machines, systems, and operations as a large and important area almost entirely neglected. He suggests that changes in the words used in man-machine systems "may produce greater improvements in performance than human engineering changes in the machine itself" (10 p. 1). He calls attention to the need for a program of applied research; including such goals as the development of criteria for evaluating operation and maintenance manuals, methods for testing them, and guides for developing them. Much of what Chapanis says about the language problems associated with man-machine systems applies directly to the overall problem of job performance aids discussed in the present report.

This section will attempt to provide a basis for further study by (a) outlining a preliminary categorization of job performance aids and (b) discussing relationships between training and job performance aids. Obviously the present report can lay only a portion of the groundwork for such study.

Bases for Categorizing Job Performance Aids

A first step in bringing order to a potential field such as job aids is to suggest some organizational structure. Five possible bases for grouping and studying job performance aids can be identified as follows:

(1) Impact on task content
(2) Time of use
(3) Information function
(4) Information format
(5) Sensory channel employed

Impact on task content. One possible approach for categorizing job aids is in terms of how such aids alter the tasks which they are designed to aid. Two such classes are suggested:

- Task supporting aids
- Task modifying aids

Task supporting aids can be identified as those kinds of performance aids which guide the performance of a task but result in the same behaviors that would be performed without an aid. A procedural checklist is one example. In contrast, task modifying aids actually change task behaviors by allowing the job incumbent to achieve a desired result without the need for performing all of the steps that would be necessary without the aid. An example here is a nomograph or a table of square roots which provides the appropriate calculations without having to work through the mathematics. The distinction between these two classes of performance aids is discussed at some length by Wulff and Berry (55,p.280).

Time of use. A second possible classification of job performance aids could be based upon the time that such an aid is employed relative to task performance. Here we can see two possible distinctions in aids:

- Off-line aids
- On-line aids

Off-line aids, or "reference aids" as Folley labels them (18,p.27), are aids which are used shortly before task performance. An example of this would be a set of instructions read by an employee before beginning a task and then remembered for a short period of time during task performance. On-line aids, on the other hand, are those which are referred to during the actual performance of the task. Folley refers to this class of aid as "cooperative" (18,p.27).

Information function. Folley suggests that job aids can also be divided according to the kind of behavior processes aided (18, p.27-28). For example:

- Information input
- Information processing
- Information output

Job performance aids which support the information input process assist the individual in identifying and recognizing certain stimuli; e.g., incoming signals or messages. Information processing aids are those used in making transformations or calculations; such as conversion tables and special purpose slide rules. Information output aids can be visualized as those which support terminal behaviors, such as overlays which are used to indicate where certain electronic elements should be attached to circuit boards.

Information format. The form in which information is presented is still a further basis for differentiating among job aids. While the variables of information format are many, the following appear particularly important to the design and utilization of job performance aids:

- Verbal
- Pictorial
  - photo/drawing
  - still/motion
  - color/black and white
- Numerical
  - formulas
- Model/mock-up

Sensory channel employed. One of the most obvious distinctions among performance aids can be made in terms of sensory modality. While sensory channels such as tactile and olfactory may someday be employed, the job performance aids in practical use today can be categorized in one of three groups.

- Visual
- Auditory
- Audiovisual

These three classes are obvious and need no explanation. The bases for deciding which channel to employ, however, are far from obvious. Information on which to base a decision is meager and at times conflicting. In one of the more recent studies of the area, Travers (51) raises serious question about the validity of many so-called principles of audiovisual presentation. He suggests that multiple sensory inputs may be of value only when the input rate is very slow. Similarly, one of the research projects reviewed in the present study reported definite problems when audio instructions were presented in conjunction with the visual presentation of an audiovisual job aid (52).

It is not intended, of course, that the tentative categories suggested here are in any way mutually exclusive. Rather, any single aid can be represented on all five classifications. Through such classification it is felt that progress can be made toward a better understanding of the functions of individual aids and their interrelationships in the overall field of job performance aids.

RELATIONSHIP BETWEEN TRAINING AND JOB PERFORMANCE AIDS

One of the major premises underlying the present study is that training and job performance aids are very closely related. Indeed, as illustrated previously in Figure 2, all three approaches - selection, training, and job aids - should be considered complementary tools in the performance development process. A prime objective in the design of certain job performance aids is to provide an alternative to extensive training and thereby reduce costs and shorten the personnel development cycle. Furthermore, in the case of off-line aids discussed in the previous section, the objective can be viewed as one of providing systematic refresher or booster training on the job. That these efforts have met with some success is supported by the information obtained in the present study.

A further indication of the intimate training-job aid relationship should be noted. No matter how simple to operate, the use of job performance aids must be taught to employees. Ideally such training should also foster employee acceptance and overcome any resistance to change that may be exhibited, particularly by the older, more experienced workers.

The development of an ideal personnel development system requires an identification of behaviors that will be obtained primarily by selection, those that will be obtained by training, and those behaviors that will be obtained by job performance aids. This implies, of course, both the freedom for personnel planners to choose among various alternatives and the availability of criteria upon which to base such decisions. In actual practice neither situation is common today. The study findings indicate, rather, that individual job aids were developed to solve some specific problem, such as excessive errors in job performance. Similarly, the criteria upon which to base such decisions are lacking. Hopefully, the decision to employ one or a combination of selection, training, or job aids will eventually be made on the basis of overall cost-effectiveness.

While a great deal more information is required, the following considerations can be identified as important in determining the respective roles of training and job performance aids:

Speed of performance. Tasks requiring particularly rapid performance; e.g., emergency first aid, suggest training rather than procedural job aids.

Task complexity. Tasks that are particularly complex and include many choice points favor job performance aids. Simple tasks, quickly learned, may not justify the costs of elaborate performance aids.

Frequency of performance. High frequency tasks suggest training emphasis. Infrequently occurring tasks imply job aids to offset the retention problem.

Length of work cycle. Lengthy tasks lend themselves to performance aiding in preference to training. Short cycle tasks may not justify performance aid costs because of the speed with which individuals are able to perform from memory.

Task stability. Tasks remaining stable over long periods of time suggest performance aids. Short lived tasks incur problems of performance aid modification.

Task flexibility. Where established task sequences are critical, procedural job aids are necessary. Freedom to vary the style of task performance reduces the necessity of procedural aids.

Task precision. Tasks requiring extremely close tolerances imply consideration of job performance aids. Tasks in which extreme accuracy is not a requirement may not warrant application of aids.

IMPACT OF JOB PERFORMANCE AIDS ON MANPOWER UTILIZATION

The major objective of the present study was to examine the results that are available concerning job performance aids and, from this, assess their actual and potential impact upon manpower utilization. Of particular concern was the extent to which job performance aids can influence selection and training, quality of job performance, and productivity. Findings that bear upon these objectives have been derived both from a study of relevant reports and by field observation and interview. Because of the exploratory nature of the study and the embryonic stage of job performance aid development, the following comments must be interpreted more as implications rather than as firm conclusions.

IMPACT ON TRAINING

The military research on procedural maintenance aids definitely supports the contention that job performance aids can compensate for lack of training and experience. The single industrial research study bearing on this point also indicates that visual job aids can enhance inspector performance at least as much as training. Similarly in agreement are the claims made in the trade journals for tape/slide devices and their ability to reduce learning time.

Generally speaking, the electronics assembly tasks surveyed required so little initial training that no deliberate attempt was made to reduce its length. Also significant is the fact that the organizations and individuals working in design and application of job performance aids represented methods engineering and quality control departments and, therefore, were not particularly interested in interfering in the basic entry level training which was the responsibility of the industrial relations department.

Requirements for specific task training and refresher training of present employees, however, have been notably influenced by job aids. The experiences of a number of companies in the field study bear upon this issue, even though their main goals were the improvement of performance quality and overall cost reduction. Results in the electronics assembly area indicate a number of instances where reductions in training time were achieved with the introduction of various job aids. Impact of job aids upon training is particularly apparent in the case of infrequently produced equipment requiring unique practices. Preservation of complex assembly techniques for later usage can eliminate the requirement for costly retraining and further can effect reduction in errors and in rejections and rework costs.

IMPACT ON SELECTION

The findings just discussed suggest definite impact of job performance aids upon training. In contrast, the research literature reviewed does not provide a basis for drawing conclusions about the extent to which job performance aids can lower selection standards. This should not be interpreted necessarily as indicating that job aids cannot serve in this capacity; but rather that the motives of the investigators were not directed with this objective in mind. The research and application reports did not attempt to study this problem; consequently no specific results in this area could be expected. It is understandable, of course, that the military organizations sponsoring the research cited were much more interested in improving maintenance quality, and possibly shortening training time to enable more rapid availability of technicians, than they were in lowering overall selection standards. Nevertheless, one can infer from the results of two of the studies (25, 40) that lower-aptitude groups can improve their performance and, in certain tasks at least, equal the performance of higher level technicians.

The results obtained from both the trade journal review and the field study also are lacking in specific information on the impact of performance aids on selection; again because there was no particular interest in exploring the problem. Clearly this is an area where additional information is required.

IMPACT ON JOB QUALITY

Quality of job performance is expressed in a variety of ways; such as number and severity of defects, amount of inspection and rework time, level and amount of direct supervision and, finally, the amount of time that must be spent in remedial on-the-job training. Military research studies explored the impact of maintenance aids on technician performance. The findings suggest that job performance aids can result in a significant reduction of errors and improvement in the number of malfunctions detected by experienced as well as inexperienced technicians. What little industrial research that has been done on job performance aids has been focused primarily upon the area of performance quality. The results clearly indicate that performance deficiencies of inspectors can be corrected by using specially designed visual aids during job performance.

Similarly, the claims in the trade journals make a special point of citing company experiences that show audiovisual aids have been a major influence in reducing the number of defects and lowering the amount of time needed for close supervision and inspection. The field study of electronics assembly also points up the contribution that job performance aids can make to raising performance quality.

IMPACT ON PRODUCTIVITY

While primary interest was directed toward reducing training time and improving the quality of military maintenance, the impact of job aids on task performance time was nevertheless studied in some of the military research on job aids. The findings indicate that use of job aids can save time, even on the part of experienced technicians. Accordingly, it appears justified to infer that job performance aids can affect productivity of maintenance personnel.

The industrial research study did not touch upon this issue; however, the trade journal claims do make some reference to the reduction in assembly time. Probably the reason that more publicity has not been given to the influence of performance aids upon task performance time is the fear of criticism and emotional reaction to the threat of task speed up. While some mention was made of an audiovisual device functioning as a pacer, this claim was overshadowed by the stress placed upon the provision for operator control over the pace at which job instructions are presented. The field survey likewise reflected a certain reluctance on the part of job aid developers to label their products as speed-up devices per se. Nevertheless, in several cases the utilization of job aids resulted in a dramatic reduction in performance time of lengthy tasks. Savings have also been noted in the amount of troubleshooting and rework time as a consequence of fewer assembly errors when job aids are used.

IMPLICATIONS FOR ROUTINE TASKS

Despite the lack of an organized technology, the evidence accumulated in this study suggests a definite role for job performance aids in industry. Even where the tasks are routine, such as in assembly operations, experiences reflected in the trade literature as well as in the field study of electronics organizations suggest that job performance aids can have a significant effect upon job quality, productivity, and certain types of training. This effect, however, diminishes as jobs are subdivided into very short cycle, repetitive tasks. Under such conditions and with a very stable work force, the costs of job aid development may not be justified on the basis of gains achieved. When adequate job performance can be achieved in a matter of hours, for example, only a minimum of orientation training on the job may be all that is justified. Nevertheless, as jobs expand in scope and tasks increase in length and difficulty relative to the capability of the work force, the utilization of job performance aids bears careful examination. Job aids also merit attention as skill upgrading becomes important. Depending upon how they are used, job performance aids can help to structure and formalize an otherwise ineffectual on-the-job training program.

To what extent such aids can relieve the burden of training in overcoming basic deficiencies among the least talented of the manpower pool remains to be determined. Historically, the motivation for individual companies to explore the role of job performance aids in utilizing low talent manpower has been lacking. This is understandable so long as industry is able to recruit at the higher levels.

However, as the nation becomes more committed to utilizing the hard core unemployed, the extent to which performance aids can contribute should be determined.

IMPLICATIONS FOR TECHNICAL WORK AREAS

While individual companies have not been particularly concerned with the problems of utilizing the lowest levels of the unskilled labor population, they have become painfully aware of problems in the skill shortage areas. How to satisfy the growing new requirements for skilled labor and how to forestall skill obsolescence of currently employed technicians and professional manpower has become one of the industry's basic concerns. The extent to which the conventional solutions of raising selection standards and expanding continuing education can keep pace with new science and technology is open to serious question.

In recognition of joint government-industry attention to this problem, representatives of the Department of Labor, the Office of Education, and all military services met with members of industry in June of 1966 at the first annual conference on Engineering Systems in Education and Training. In his keynote address, the Honorable Thomas Morris, Assistant Secretary of Defense (Manpower), outlined five basic objectives. One objective is particularly germane to this study:

> "We need to expose more of our people to more information on an 'as needed' basis. With devices for information storage and retrieval, random access, and high speed communications - it seems to us that the time is fast approaching when knowledge can be more widely and immediately accessible - both for classroom training and for use on the job, thus minimizing the amount of knowledge which must be gained in the classroom itself." (37, p. 12-13)

At this same meeting the Honorable Samuel Ganz, Deputy Manpower Administrator, Department of Labor, spoke of the need for accelerated training in the critical skill shortage areas (37, p. 160). This accelerated training approach would involve the use of new techniques in education technology coupled with the "type of work simplification methods used during World War II." Because of the pressing need to utilize the seriously disadvantaged segment of the population, Mr. Ganz suggests consideration of redesigning positions in short supply and creating new, lower level positions. While not identified as such, a program of "accelerated training" could very well incorporate the benefits of applying information technology in the job enviroment as suggested by Secretary Morris.

As indicated throughout the present report, the military agencies have been particularly sensitive to the increasing gap between manpower resources and the requirements for technicians to operate and maintain increasingly complex man-machine systems. One potential solution that continues to be explored with growing emphasis, as Secretary Morris implied, is the technology for providing improved job-based communication at the point of use.

The exploratory survey in the patient care area has provided one example of the limited usage of job performance aids in a critical skill area. While the relatively few information aids in use serve an important function, at this stage one can only speculate on the extent to which a comprehensive, formalized program of job performance aid development could demonstrate important gains in manpower utilization through improving human performance, reducing training problems, and expanding the potential reservoir of applicants. Because of the range of skills represented in the health care field, a systematic program in this area could have significant impact not only upon this one critical area but upon many other work areas as well.

Recommendations

RECOMMENDED RESEARCH AND DEVELOPMENT

The results of the present study demonstrate the potential of job performance aids. More information must be accumulated, of course, before the practical significance of job aids can be exploited fully. Two major areas of recommendations are provided in the hope of contributing to the technical progress of the field. Specific recommendations for development activities are presented first, in keeping with the proper concern of the Labor Department for practical developments in the field of manpower utilization. Following this is presented an outline of recommended research studies, the results of which would contribute to the long term growth and refinement of the job aid field.

RECOMMENDED DEVELOPMENT

The lack of a formalized job performance aid program in civilian work has been identified as a gap in the field of manpower utilization. Until such time as a systematic program is developed and demonstrated, the field will remain the hodgepodge that it is today; largely unproven in its potential claim as a tool for manpower utilization. Accordingly, it is recommended that such a program be undertaken within a skill shortage area involving a wide enough array of jobs and tasks such that the results of the program could be generalized to a broad range of task levels.

Based upon the experience gained during this preliminary study effort, the patient care field could well serve as a model for such a developmental effort. The field is fast becoming a prime focus of concern as personnel shortages grow worse and the demands for quality health services increase. New patient care jobs are being explored to relieve the burden upon the overloaded professional and to provide the new skills required by the rapid increase in complex medical equipment and new techniques. Variations in education and training programs are being studied and expanded utilization of sub-professional personnel is gaining attention. The present usage of performance aids, limited as it is, suggests a recognition of the role of external information assistance at various skill and professional levels. The critical importance of the patient care tasks and the need for extreme accuracy and attention to detail, coupled with problems of high personnel turnover and the need to improve the efficiency of personnel utilization, further argue for consideration of the patient care area as a "test bed" for job aid demonstration.

Besides the benefits that can be expected to accrue to the patient care field directly and to other work areas indirectly, the recommended program could develop and refine procedures and other guidance for use in later programs of job aid development.

While certain earlier applications of elaborate job aids met with only mixed success in the electronics assembly area, many applications have proved to be of value and new aids continue to be developed. It would appear that more intensive development activity is warranted as part of the nation's overall program to relieve skill shortages in the electronics area. The framework for the job performance aid field suggested in the present report could serve as a basis for developing and evaluating specific types of job aids for supporting electronics job behaviors. Findings in this study suggest that new applications could most profitably focus on complex, long cycle, precision tasks. Included in this program should be the development of functional characteristics and detailed design specifications leading to the production and field evaluation of specific job performance aids.

RECOMMENDED RESEARCH

The almost complete lack of job performance aid research in the civilian sector indicates that a great many areas exist where new knowledge must be developed to support the long term growth of the job performance aid field. Four major questions are suggested as worthy of priority consideration:

1. What is the potential contribution of job performance aids for reducing basic aptitude requirements?

This question was suggested earlier as one deserving study as part of the nation's effort at improving the utilization of the "hard core" unemployed. Despite the pressure for immediate results in this area, it is believed that a research program into certain variables of job aid design should be conducted in order to provide a basis for future demonstration efforts.

2. What is the ideal relationship between job performance aids and training aids?

The apparent similarities and differences between training aids and job performance aids were identified in the present report. Much more remains to be done to explore the mutually supporting roles of these two techniques, the implications for functional and physical design characteristics, and the optimum integration of both techniques in an overall personnel development sequence. Such a study would be particularly helpful to the job performance aid field because of the knowledge that could be gained from the older, more developed training aid field.

3. What is the optimum sensory channel for various types of job performance aids?

The question of which sensory modality, or combination of senses, is best utilized in various performance aids is in need of solid experimental findings. The evidence as indicated in this report is far from conclusive and, in some cases, is contradictory. There is no question that information in this area will be of major, long term benefit in fostering an effective performance aid program.

4. What are the implications of applying new information handling technology to the design of job performance aids?

A comprehensive study of new technical developments should form a part of any long range program of job aid research. Specifically included in such a study should be an analysis of major advances in the techniques of information organization, formatting, storage, retrieval, updating, and presentation. Fields of endeavor such as computer application, microfilming, closed circuit TV, video tape recording, and facsimile reproduction merit special attention as they may affect the future of job performance aid development and utilization.

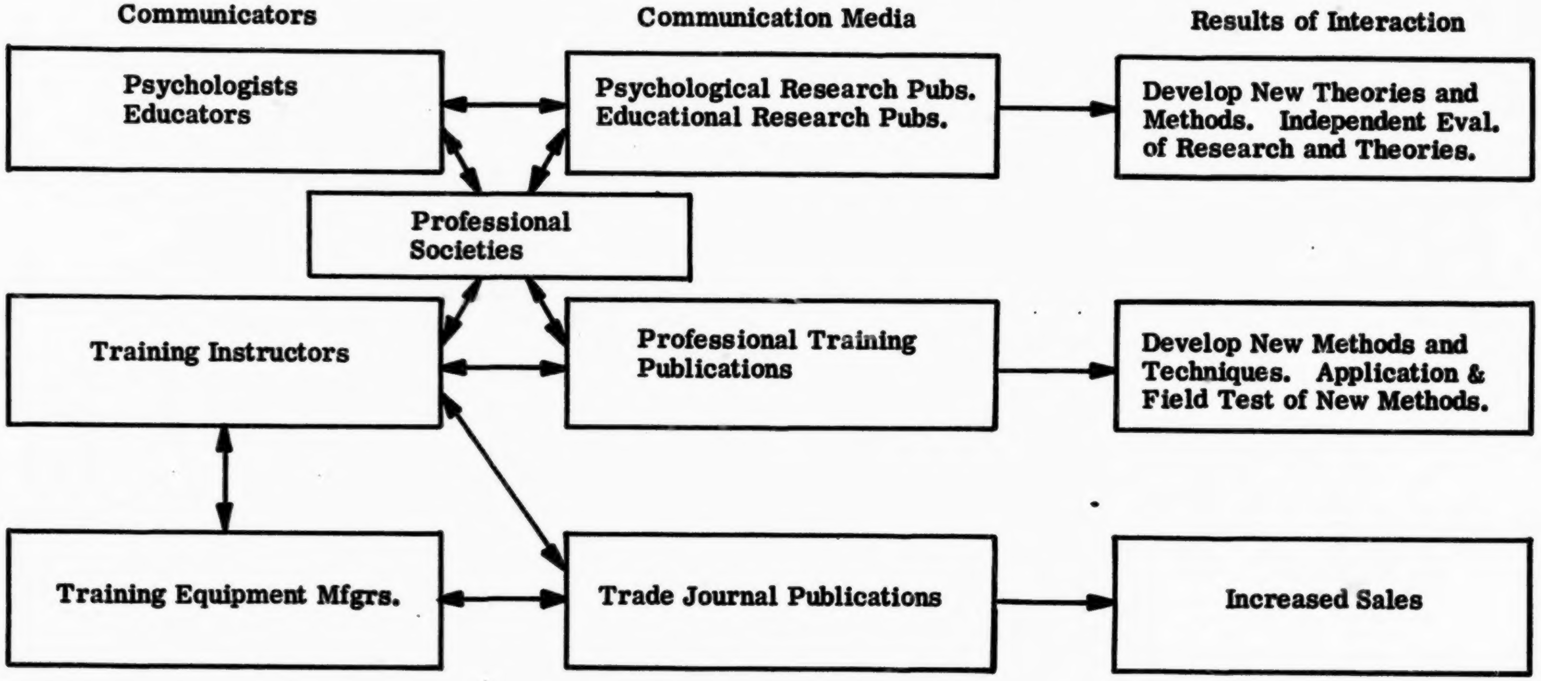
SUGGESTED POLICY IMPLICATIONS

It is premature to suggest firm policy on the basis of the exploratory research reported here. Certainly, the results of further study must be accumulated before any wide-scale policy changes could be implemented. At the same time, however, even the results of this one investigation can legitimately suggest directions for the anticipation of policy.

In attempting to develop a better understanding of the cyclical growth pattern of industrial AV performance aids and the general lack of progress in the area, the investigators looked closely at the nature of the process by which relevant job performance aid information is being disseminated. As a contrast to this situation, the field of industrial training and its communication links were similarly analyzed. Underlying this activity was the hypothesis that the lack of growth in the job aid field could be attributed, at least in part, to poor communication. Stated more broadly, it was hypothesized that the growth of a technical field of specialization is influenced by the number and quality of communication links supporting the field.

The results of this preliminary analysis of communication processes in the job performance aid area as compared with the training field are shown in Figure 3. If we look at the upper portion of Figure 3, we can see that for the training field the nature and types of knowledge generators and communicators are indeed significant. Similar to many other professional areas, the training field is supported by several major independent sources of knowledge and transmitters of information; namely psychologists, educators, industrial training personnel, and manufacturers of training equipment and materials. Still another source of information is the professional training society; e.g., American Society for Training and Development (ASTD). While overlapping the other groups, these organizations serve as an entity to stimulate and communicate relevant information. Training societies, particularly at the local level, contribute significantly to knowledge dissemination by providing a vehicle for face-to-face communication.

COMMUNICATIONS NETWORK SUPPORTING THE TRAINING FIELD


Communicators
Communication Media
Results of Interaction
Psychologists Educators
Psychological Research Pubs. Educational Research Pubs.
Develop New Theories and Methods. Independent Eval. of Research and Theories.
Professional Societies
Training Instructors
Professional Training Publications
Develop New Methods and Techniques. Application & Field Test of New Methods.
Training Equipment Mfgrs.
Trade Journal Publications
Increased Sales

COMMUNICATIONS NETWORK SUPPORTING JOB PERFORMANCE AID (JPA) FIELD

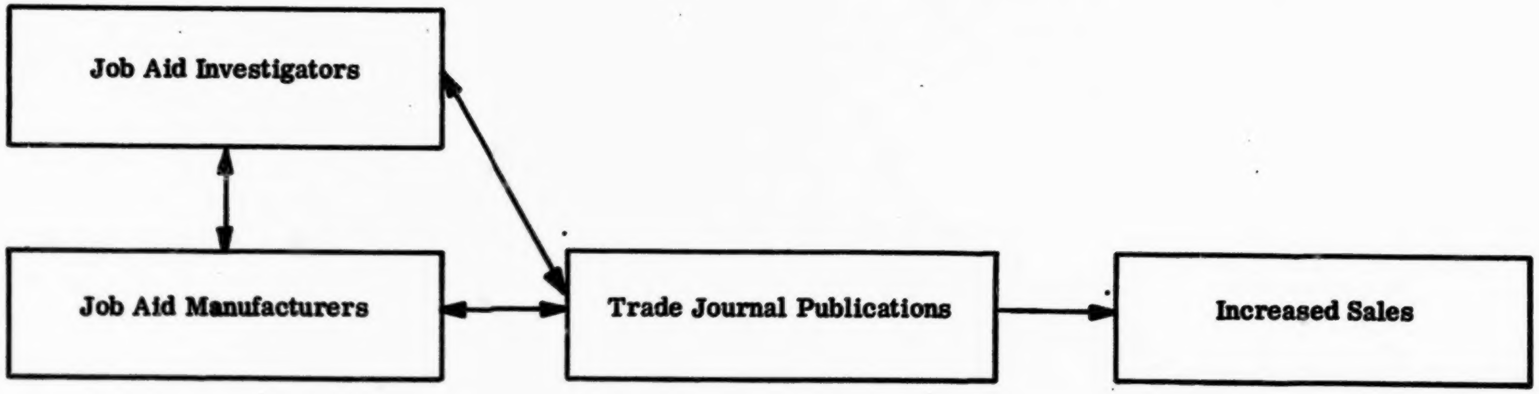

Job Aid Investigators
Job Aid Manufacturers
Trade Journal Publications
Increased Sales

FIGURE 3

PRELIMINARY ANALYSIS OF COMMUNICATION PATTERNS IN THE INDUSTRIAL TRAINING AS COMPARED WITH JPA FIELDS

Supporting the varied nature of the knowledge generators are a number of different media available for communicating significant research and application results. It can be assumed that this rich communication network, with its opportunity for claim and counterclaim, for theory and anti-theory, contributes not only to the transmission and application of new knowledge but also, through the feedback mechanism, directly fosters the generation of new knowledge. Particularly significant from the standpoint of the training man in industry, the lone practitioner can easily keep in the mainstream of new training developments. The danger of repeatedly re-inventing the wheel is materially reduced in respect to the training field. One can hope with some degree of confidence that through this mechanism the progress of training technology moves ahead somewhat each year.

Now in contrast, if we look at the lower portion of Figure 3, showing the job performance aid area and its communication network, we find an altogether different picture. Here, for all practical purposes, only two sources of knowledge exist -- the individual job performance aid developers and the manufacturers of job performance aid equipment. Based upon our exploratory survey, it appears that individuals concerned with informational job aids are working in at least partial isolation. Their major source of information comes from very informal and infrequent contacts with their colleagues in other companies or from salesmen representing particular job aid devices. Our experience suggests that, because of the lack of information, it is not uncommon for industrial engineers in one company to be starting a job performance aid development effort without the benefit of knowledge from similar programs already completed by other engineers working in different companies. The need for more formal communication links was recognized by a number of the participants in our survey.

Because of the lack of established communication channels, the salesman of job aid devices has become a rather key figure in the communication flow. Without minimizing the services of the salesman, one can seriously question the situation where he becomes the major, if not the only, transmitter of technical information. Questions of objectivity and of communications effectiveness can certainly be raised. And yet, when no other channels exist, the investigators have little choice but to rely upon the salesman to bring various company investigators into contact. In fact, during our field study, one of the respondents was surprised to receive separate requests from two other companies to share experiences in the use of job performance aids. Believing that the present report had been published and that this was the stimulus for such requests, he contacted the investigators for further information. After some discussion, it was agreed that very likely one of the salesmen had been instrumental in these requests for information sharing.

The need for better and more extensive information was also reflected in the particularly enthusiastic cooperation the investigators received in nearly every company contacted. Requests to receive a copy of the survey report were almost universal.

In the light of this dearth of professional communication in the job performance aid field and the probable negative impact upon technical progress, it is suggested that the Department of Labor give consideration to what positive role it might play in fostering improved communications and, in turn, greater progress in the field. It is hoped that reports of studies bearing upon job performance aids, such as this one, can be of some help in laying the groundwork for this communication. Also, it is suggested that whenever a related study of manpower utilization, training, etc., is undertaken under the Manpower Development & Training Act or related programs the investigators be encouraged to give some attention to the existence of job performance aids and the potential development of improved aids. The degree to which independent investigators recognize this area and include it as an item in their studies will contribute significantly to the objective evaluation of the strengths and deficiencies in industrial job aid development.

Appendices

APPENDICES

APPENDIX A

ANNOTATED BIBLIOGRAPHY RELEVANT TO JOB PERFORMANCE AID FIELD

1. Ammerman, H. L. Performance Aids for Junior Officers. Alexandria, Virginia: The George Washington University, Human Resources Research Office, HumRRO, Technical Report 65-11, 1965.

This study summarizes the comments and suggestions of air defense battery officers concerning the types of managerial aids that would be useful for junior officer performance and learning. A suggested format for a handbook was developed covering what the inexperienced unit officer needs most to know about operational and system checks of electronic equipment. A loose-leaf format containing pocket size (5 x 8 inch) cards was recommended. The author concluded that: (a) many small unit commanders in the air defense field desire additional job aids for newly assigned junior officers; (b) such aids should be designed for quick and easy use at the job location and should emphasize essential skills and knowledges required early in the job; and (c) existing guidance in manuals and directives is helpful but easily readable summaries are needed for the very inexperienced officer who is expected to perform as a manager of technicians soon after assignment to a new job.

2. "Audio-Visual Aids Join the Assembly Line." Supervisory Management, January 1963, 8, 51-2.

This article relates how workers with meager skills and a minimum of training are doing complex assembly jobs with the aid of audio-visual machines. Basically, such systems employ the use of a slide projector with a screen and a tape recorder with earphone attachments; all of which are timed to the assembly job to be accomplished. This approached has been used primarily on production lines where complex electronic gear is assembled. The audiovisual system guides the worker through the process, with the slide projector visually depicting each step while the taped script describes the procedure. Keyed pulse codes on the tape synchronize the slides with the script and music is inserted in the script for time intervals between end of instruction and completion of process. According to the article, the average program of 15 minutes of tape and 30 slides will cover approximately one to one and a half hours of assembly work. It is claimed that assembly time can be cut by 50% with a 90% reduction in rejects.

3. "Audio Visual Method Gives Faster, Better Production." Western Manufacturing, January 1962, 23-25.

The article describes the audiovisual (AV) instruction units for workers engaged in electronics manufacturing at a specific company. At the time of this article, these units were used in 20 assembly programs and 18 inspection programs varying in application from combined color slide/tape to slide or tape only. In actual electronic manufacturing at the plant, it was claimed that AV units have achieved saving in four major areas; learning time for assemblers and inspectors reduced by 45%, assembly time and inspection time by 50%, defects at inspection by 49%, and discrepancies in test by 44%. AV techniques as a communication tool were best applied when work was complex, time consuming, and critical in regard to assembly steps and quality of workmanship. Indications were that assembly output should exceed 35 units for optimum AV use and that high engineering change rates, small quantity production, and simple or repetitive assembly steps limited the value of AV programming. Results suggest that reduction in assembly time is a major source of cost savings. Improved operator performance stemmed from compulsory standardization in which the worker had no other information from which to work. The article pointed out that before an intelligent evaluation can be made by other manufacturers regarding the economics of using AV on the assembly line, they must consider complexity of assembly, quantities and durations of lot runs, potential quality and test problems, and labor turnover.

4. Baum, S. Uses of Nomography in Modern Research. San Francisco: U. S. Naval Radiological Defense Laboratory, Reviews and Lectures No. 58, June 1958.

The author discusses the use of nomographs (alignment charts) at the U. S. Naval Radiological Defense Laboratory. Specific examples are provided to illustrate the use of nomographs for expediting routine calculations and permitting technical assistants to carry out computations whose bases are beyond their mathematical skills. Among the advantages claimed are savings in time and prevention of errors. Only eighth grade arithmetic is said to be needed rather than college level mathematics otherwise required. Baum suggests considerations of including nomography in the engineering curiculum.

5. Berkshire, J. R. Field Evaluation of a Troubleshooting Aid. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, AFPTRC-TR-54-24, June 1954. (AD 537 25)*

The development and preliminary evaluation of a set of troubleshooting aids are described by Berkshire. The aids consisted of color-coded schematic diagrams and written troubleshooting instructions called trouble locators. Results indicated that use of trouble locators reduced significantly the errors made by both experienced and inexperienced personnel and enabled inexperienced personnel to identify malfunctions in about the same time as the more experienced men. The procedures set forth in the trouble locators were apparently specific enough to make the color-coded schematics unnecessary for troubleshooting.

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[*] Refers to the publication access number assigned by the Defense Documentation Center. References carrying such numbers can be obtained through the Clearinghouse for Federal Scientific and Technical Information, Department of Commerce.

6. Bio-Dynamics Inc. Design and Use of Information Systems for Automated On-The-Job Training. Vol III: Experimental Use of Three Instructional Concepts. L. G. Hanscom Field, Mass.: Electronic Systems Division, Air Force Systems Command, ESD-TDR-64-234, March 1965. (AD 616 544)

This report is one of a series of five related reports dealing with the development of design principles for automated training subsystems which could be built into future information systems. Three experiments involving novel teaching concepts are described. The results of the experiments indicate that: (a) a teaching program ordered according to the discovery principle significantly reduced errors and performance time over that observed after training with a conventional training manual; (b) slides projected directly onto a control console, together with a taped lecture, were found to be an effective method of presenting an automated training program; and (c) graphical logical flow diagrams were found to be efficient instructions for teaching procedures for performing a querying-reasoning task.

7. Bio-Dynamics Inc. Design and Use of Information Systems for Automated On-The-Job Training, Vol V - Final Report. L. G. Hanscom Field, Mass.: Decision Sciences Laboratory, Electronic Systems Divison, ESD-TDR-64-234, April 1965. (AD 616 545)

This is the final report of a series of five covering research on the development of design principles for automated on-the-job training for information system operators. The methods and results of the experiments detailed in the previous reports are summarized here. Conclusions and recommendations based on the overall research program are provided. One of the conclusions stated was that the slide/tape instruction programs can be used to provide on-the-job training or serve as performance aids with operational equipment. Since this technique can be evaluated in the field without requiring equipment modification, it was recommended that such a program be developed and used to meet an existing training need.

8. Bronson, Z. "Instrumentation and the Management of R&D." Research/Development, August 1966, 23-36.

In this article Bronson explores the subject of R&D instrumentation and its effect on scientific and technical manpower. The need for instrumentation is shown to generate forces which cut across the entire structure of R&D activity and influence both the rate and quality of progress. The study findings indicate "virtual unanimity of view that dependence on instrumentation is increasing and that it (1) can interfere with the freedom of research choices, (2) can involve changes in manpower requirements, and (3) can be the medium for promoting or inhibiting individual creativity and organizational productivity."

9. Brown, H. T. Evaluation of a Head-Worn Audio-Visual Aid. Fullerton, California: Ground Systems Group, Hughes Aircraft Company, FR 64-10-333, November 1964.

A laboratory model of a head-worn film strip viewer together with audio tape was evaluated as a vehicle for presenting programmed audiovisual guidance in the performance of maintenance tasks. The head-worn device is a lightweight unit (approximately 30 oz) which holds a 35 mm film strip of up to 75 frames. The optical system includes a semitransparent mirror which allows the user to attend to the reflected image or to look through the mirror to his environment. The film viewer was used in the laboratory to assess its usability in relation to certain display and environmental variables. In addition, the device was compared with a much larger (22 lb) audiovisual device whose effectiveness had been previously established. While some viewing conditions are more difficult than others, the device was deemed useful under a wide range of conditions. Specific viewing difficulties and means for offsetting them were identified and discussed. When the two audiovisual devices were compared as aids to aligning radar display equipment, they were found not to differ significantly in terms of alignment times; only subjects and trials produced statistically reliable performance differences. Of the 12 users, 6 preferred the head-worn device, 4 preferred the comparison device and 2 expressed a preference for maintenance manuals. Subject evaluations of the two devices are presented along with a list of design improvements which the authors recommend be incorporated in future versions of the head-worn device.

10. Chapanis, A. "Words, Words, Words." Human Factors, February 1965, 7, 1-17.

The author calls attention to the area of language and the words attached to tools, machines, systems, and operations. He labels this area as almost entirely neglected and states that "changes in the words used in man-machine systems may produce greater improvements in performance than human engineering changes in the machine itself." Examples and illustrations of language problems are included to support his argument. A program of applied research on practical language problems is outlined. Among his research suggestions are a critical incident study of language problems encountered in man-machine systems; the development and experimental validation of principles for structuring short sentences; and the development of methods and criteria for designing and evaluating instruction manuals.

11. "Color-Sound Slides Speed Assembly." American Machinist/Metalworking Manufacturing, April 30, 1962, p 108-110.

This article describes the Hughes Aircraft Videosonic system, how it is implemented and what the results are. The videosonic concept is described as going one step beyond the audiovisual approach in that it takes into account the assembler's time and physical motion required to get parts and tools; thus providing a "packaged" environment for each worker. In addition to the basic audiovisual equipment, each work station is equipped with adjustable parts bins, vise-type work holders, and receptacles for all necessary tools and soldering irons. It was indicated that when assemblers were transferred from one job to another, the Videosonic method reduced retraining time from a month to a week to reach 80% or better efficiency. In addition, assemblers experienced about a 33% increase in individual productivity and a 60% or more reduction in rejects. Other results included more uniform productivity, freeing of supervisory personnel from instruction duties, and a 50% cut in learning time for assemblers. Further indications were that with its use, an unskilled assembler could achieve at least 80% efficiency on a new job in about a weeks training time and three days experience, as contrasted to more than 30 days for the same level of efficiency without Videosonic equipment. According to the article, a typical complex assembly of 3210 parts, previously requiring 160 hours to assemble, can be reduced to 65 hours of assembly time with Videosonic equipment.

12. Davis, R. M. Effective Technical Communications: Mechanical Description - Experiment II. Wright-Patterson Air Force Base, Ohio: Air Force Institute of Technology, Technical Report 65-1, 1965.

Results of a study to determine the relative effectiveness of different forms of written technical material are presented in the report. The effects of four variables upon written communication process were tested by varying the order and content of a technical description presented to four groups of young men classified as: bright with technical interest, bright without technical interest, average with technical interest, below average with technical interest. Subjects read material with varying content and completed a comprehensive test. Results indicated that: size and shape could best be presented by drawings, or drawings plus verbal descriptions for bright and average readers; while use of drawings to denote size and shape significantly reduced reading time for all groups.

13. Day, W. F. and Beach, Barbara R. A Survey of the Research Literature Comparing the Visual and Auditory Presentation of Information. Wright-Patterson Air Force Base, Ohio: U.S. Air Force, Air Materiel Command, AF Tech Report 5921, November 1950.

A literature survey, conducted under a USAF Air Materiel Command contract, was made of existing articles and studies relating to transmission of information via visual and auditory channels. Results of the survey, covering 34 articles dating from 1894 through 1946, indicated that the literature did not support the thesis that one system was superior to the other as a communication channel; with one-half the studies supporting visual presentation, and the other half supporting auditory. Evidence indicates the combined visual/auditory presentation to be generally most efficient. Factors influencing the use of one channel over the other are identified and areas for further investigation are suggested.

14. "Design Evolution Gains Maximum Utility." Aviation Week & Space Technology, September 7, 1964, p 106-112.

Included in this article is a description of the Smiths Aural Diagnostic Inspection Equipment, known by the acronym of SADIE. The device was reported being used by British European Airways for maintenance of the Smiths flight control system of the Trident jet transport and also being evaluated by the Royal Air Force. SADIE consists of a small (10 lb), specially designed magnetic tape player and hand-held controller. A prerecorded tape, housed in a cartridge which slips into the tape player, contains a series of detailed instructions for system troubleshooting on one track, while another track on the same tape contains the troubleshooting sequence logic, recorded in digital form. If the desired result is observed, the chief maintenance man pushes the "yes" button on his small hand-held controller and the tape automatically advances to the next test instruction. If the prescribed result is not obtained, the "no" button is pushed and the tape advances to a different test instruction. A third button on the hand controller makes it possible to repeat any instruction. Depending upon the results of each test, the tape automatically proceeds in logical sequence until it finally identifies the malfunctioning element. The tape also refers the maintenance man to a specific page in a small printed manual which shows interconnecting wires, replacement procedures, and similar information needed. It is stated that the use of the SADIE not only permits personnel with lower skills to troubleshoot complex systems successfully, but also tends to equalize the time required to locate any malfunction in the system. Company experience indicates that SADIE permits the isolation of any malfunction in the flight control system in less than 30 minutes.

15. Duggar, B. C., Rosenberg, R. C., Sheridan, T. B., Mayer, Sylvia. Design and Use of Information Systems for Automated On-The-Job Training - Vol IV Graphical Symbology and Logic Diagrams for Use as Training Aids. L. G. Hanscom Field, Mass: Electronic Systems Division, Air Force Systems Command, ESD-TDR-64-234, January 1965. (AD 616 551)

This report, the fourth in a series of five, describes the development of a graphical symbology and logic diagraming technique for use as a training aid. Symbols and the logic diagraming technique were refined by application to several tasks and were judged to be useful: (a) for supplementing written instruction manuals, (b) as a teaching aid without text, and (c) as a performance aid when displayed on an operational console.

16. Elliott, T. K. Effect of Format and Detail of Job Performance Aids in Performing Simulated Troubleshooting Tasks. Wright-Patterson Air Force Base, Ohio: Aerospace Medical Research Laboratories, AMRL-65-154, 1966. (AD 629 992)

The effects of performance aid format, performance aid detail, and subject aptitude on the performance of paper and pencil data flow analysis tasks were measured. Sixteen subjects were used in a 2 x 2 x 2 design. Eight of these subjects scored between the 75th and 95th percentile on the electronic aptitude index of the

Airman Qualifying Exam; while the other eight scored between the 40th and 60th percentiles. Each subject received approximately 30 hours of training and practice, following which he was tested at one of the two levels of detail. Each subject was tested for 9 hours with aids in the block diagram format and for 9 hours with aids in the list structure format. Order of testing was counterbalanced across subjects. Criterion measures were (1) number of problems attempted; (2) percentage of errorless localizations; (3) number of localization errors per problem; (4) number of localization errors of exclusion per problem; and (5) percentage of errorless isolations. Subject aptitude was found to have the greatest effect on the accuracy with which subjects performed both localization and isolation tasks. Level of detail had the greatest effect on their speed (low level of detail subjects solved nearly twice as many problems as high level of detail subjects). Performance was better with the diagrams than with list structures.

17. Folley, J. D., Jr. A Preliminary Procedure for Systematically Designing Performance Aids. Wright-Patterson Air Force Base, Ohio: Aeronautical Systems Division, Air Force Systems Command, Report ASD 61-550, October 1961. (AD 270 868)

A procedure is presented for use of human factors specialists to design performance aids pertaining to operating and maintaining man-machine systems in the military. The procedure is based on analysis of the kind of behavior required of the task performer and, presumably, could be generalized beyond military application. Although fairly detailed guidelines are given for parts of the procedure, considerable judgment is still required. The author recognized the procedure as untried and admittedly as having weaknesses; offering stopgap solutions to problems requiring more research and development. Four steps in the design of performance aids are presented: (1) identification of task elements for which aids should be provided - this involves describing the job and its component tasks, and analyzing each task element; (2) determination of appropriate functional characteristics of aids for task elements - what the aid must do, not how it is done; (3) specification of the physical characteristics of the aids to carry out the functions - this involves combining the functional characteristics into appropriate groupings and determining the most suitable method of performing each combination of functions; and (4) evaluation, modification, and updating of the aids - this ranges from a review of the steps taken in designing the aids to an empirical tryout with a mockup or actual equipment.

18. Folley, J. D., Jr. Research Problems in the Design of Performance Aids. Wright-Patterson AFB, Ohio: Aeronautical Systems Division, Air Force Systems Command, ASD-TR 61-548, October 1961. (AD 270 866)

Analyzing the information needs for the process of incorporating performance aids into a man-machine system is used as the vehicle for identifying significant problems in need of solutions. The process is structured as (1) determining the need for performance aids, (2) determining how the aids should fill the need, (3) selecting or creating devices to fill the need, (4) evaluating the effectiveness of the aids, and (5) coordinating changes in aids with changes in the needs. The argument is made that aids should be considered early in systems development for greatest contributions, but that they have utility at whatever stage of development they are designed. The most fundamental research problem is the need for a sound scheme for describing tasks and behaviors, in conjunction with development of a model of transfer of performance capability from task to task. Another highly important area for methodological research is the capability for human performance, equipment performance, and system performance to be specified and measured in directly comparable terms. A third methodological problem to be solved is that of measuring system effectiveness per unit of cost, with emphasis on including human factors in more quantitative terms than possible to date. The major problem to be solved by empirical research is to obtain data on the characteristics of human performance in realistic situations. The emphasis here is placed on multivariate studies to determine the relationships among significant variables that affect performance. A longitudinal approach is suggested, in which a few subjects are studied for long term periods as they become highly skilled on some tasks.

19. Folley, J. D., Jr. and Munger, Sara J. A Review of the Literature on Design of Informational Job Performance Aids. Wright-Patterson Air Force Base, Ohio: Aeronautical Systems Division, Air Force Systems Command ASD Tech Report 61-549, October 1961. (AD 270 867)

Nine sources of military reports and psychological journals were surveyed for references pertaining to research on the design of performance aids. The information from a review of 57 relevant references is presented as an annotated bibliography with a general discussion on the findings. The major portion of research reviewed was performed for the Air Force and was completed prior to 1958. None of the studies attempted to identify the significant variables to be considered in the design of aids. The preponderance of the work was concerned with developing and trying sample aids. The tryout of specific aids yielded limited information about the relationships among the conditions that were manipulated and measured. The general discussion of findings was organized under the headings: "Procedures for designing performance aids," "Determining the functional characteristics of aids," and "Determining physical characteristics of aids." The planned headings of "Determining the need or desirability of aids," "Evaluating the effectiveness of aids," and "Coordinating changes in aids with evolving changes in job structure" were omitted because not enough information was available on these topics. Major emphasis was given to studies using printed performance aid material, although some studies report on the use of auditory aids. Performance aids for simplification of troubleshooting have received the most attention, showing that procedural aids can facilitate such performance. The extent to which other kinds of aids can facilitate performance of other kinds of tasks is unkown. Useful guides for performance aid design were found, but explicit methods for designing aids were lacking. No adequate solutions to the problem of determining information requirements of a task were available, and little guidance was found for making tradeoffs between information in the performance aid and information learned during training. It is suggested that more consideration be given to establishing information about human performance; such as definitive statements about the conditions under which errors are likely to occur.

20. Folley, J. D., Jr. and Shettel, H. H. Tryout of a Preliminary Procedure for Systematically Designing Performance Aids. Wright-Patterson Air Force Base, Ohio: 6570th Aerospace Medical Research Laboratories, MRL-TDR-62-20, April 1962. (AD 283 605)

The performance aids recommended by applying the design procedure to a sample of task data for an operational missile system were compared with those recommended on the basis of observation and analysis of task performance in the operational situation. Detailed application of the procedure was made for a small number of the 135 troubleshooting tasks that had been selected. It was concluded that, for the most part, the performance aids recommended by using the procedure would meet the needs of the operational situations quite well. One problem obscuring the evaluation was the fact that the level of performance in the field was not adequate to meet system requirements. It was also noted that the personnel for whom the performance aids were designed rejected the idea that their jobs could be proceduralized; yet they proceeded to develop procedures comparable to those produced by the task analysts. The major change made in the procedure as a result of the tryout was to require performance aids for every task in a system, except for tasks in which use of the aid would result in too slow performance. Several recommendations were made for performance aids to be used with the missile system, including a cross-index file to help locate the appropriate procedural checklist. Three research problems were identified: (1) What is optimal format and level of detail for a procedural task checklist? (2) What combination of performance aids and training is most effective for developing troubleshooting ability? (3) By what means can behaviorally critical aspects of tasks be identified?

21. Harker, W. A. "Audio-Visual Learning - It's More Than Hear-Say!" Electronic Industries, August 1961, p 103-105.

This article describes the function, application, and results of the Videosonic system developed by Hughes Aircraft Co. Consisting of both information programing and display equipment (resembling a portable TV set), the AV system was designed primarily for communicating complex information to electronic assembly line workers. Where used for on-the-job instructions, properly programmed material results in accurate and concise task definition which shows and tells exactly how each step is to be performed, in sequence, and at the precise moment it is to be done. Thus, the most complex of operations can be easily understood. For example, learning time for a new operator normally requires an average of 10 times the allowed standard time to produce the first unit. It was stated that Videosonic aids in reducing this to 4-1/2 times the standard for the first unit with third units produced at the standard rate. Immediate increases in productivity of 70% are not unusual. The most striking results, according to the author, are improved quality and reliability in workmanship and products. Where an average of five and one-half quality defects per unit had been experienced, a reduction to one-half defect per unit was achieved upon introduction of the system.

22. Henneman, R. H. & Long, E. R. A Comparison of the Visual and Auditory Senses as Channels for Data Presentation. Wright Air Development Center, WADC Tech Report 54-363, August 1954. (AD 61 558)

This study was undertaken to provide communication engineers and psychologists with information that might be used to support auditory/visual trade-off decisions in equipment design. A taxonomy was developed to permit multiple classification of results and conclusions derived from a survey of literature relevant to the study. The authors state that the question of relative superiority of vision vs audition for communication channels cannot be answered without first determining the conditions and purposes. Variables to be considered are: types of responses; e.g., comparison, quantitative, etc.; operator variables; e.g., previous habits; and environmental constraint; e.g., ambient noise, excessive vibration, etc. Suggested applications for visual auditory either visual or auditory, and dual audiovisual presentation of information are presented in tabular form with accompanying estimates of confidence based upon applicable research.

23. Hill, D. A. & Tamsen, J. J. "Videosonic System Instructions Raise Quality Standards." Industrial Quality Control, July 1961, 15-20

In an effort to prevent or diminish human error during assembly, Hughes Aircraft Co. developed the Videosonic system (an audiovisual 35 mm color slide and tape display). In describing its development, application, and results, the article identifies this system as "one of the most powerful tools every developed for communicating intelligence in such a manner as to assure accuracy, guarantee standardization, and facilitate the understanding of the most complex data to individuals from all walks of life and of varying abilities." It offers flexibility in that presentations may be used for long or short run projects, retained, and when needed again are implemented without the long indoctrination time required to retrain a worker. Noted improvements due to its use have been in the general areas of reliability, quality, production, and employee relations. At the time of the article, the Falcon Missile at Tucson Arizona was assembled, inspected, tested, and supported in the field through this system. A unique application of the system was its use in filling out employment questionnaires and security clearance applications; thus replacing a somewhat complicated instruction sheet. In regard to reliability, a 50 to 60% first-test acceptance ratio increased to between 75 and 85% on all electronic packages submitted. The most complex chassis in the Falcon Missile increased its first test average from 50% acceptance to 84% acceptance with Videosonic application. In regard to cost savings expressed in terms of costs expended and costs saved, Hughes experienced a crossover point in the third year with savings exceeding costs during the following years. In total, the authors claim that the Videosonic system has improved communications, reduced costs, provided ability to adapt quickly to new market situations, and has greatly improved the reliability and quality of products.

24. Hoehn, A. J. & Lumsdaine, A. A. Design and Use of Job Aids for Communicating Technical Information. Lowry AFB, Colorado: AF Personnel and Training Research Center, AFPTRC-TR-58-7, January 1958. (AD 152 109)

This report summarizes a number of research and development efforts on the design and utilization of job aids undertaken by the Maintenance Laboratory of the Air Force Personnel & Training Research Center. The primary objective of the research was to identify and test the effectiveness of improved techniques and procedures for the design of job instructions, or informational job aids, that could reduce the amount of training required for technicians and increase the efficiency of their job performance. Prototype materials and methods for the maintenance of flight control systems and their components were formulated and tested; several experiments on factors affecting the comprehension of printed verbal instructions were conducted; exploratory research on audio presentation of instructions was accomplished; and the design and fabrication of a prototype model of a special-purpose magazine loaded sound film projector was completed. Among the conclusions drawn were: (a) carefully designed job aids can reduce training requirements, improve the utilization of lower skilled airmen, and increase the reliability of their performance; (b) for maximum efficiency in the development of maintenance capabilities, procedures should be developed to plan and implement job aid materials in a manner closely integrated with training materials; (c) proceduralized, step-by-step instructions have been constructed so as to minimize requirements for advanced training even for such difficult tasks as troubleshooting of quite complex equipments; (d) better methods of job-task-analysis emphasizing the behavior processes which the job aid materials are to support and the conditions which foster these behavior processes are required for designing of job aids; (e) an automatic sound film viewer was demonstrated as technically feasible, and a preliminary study of a prototype of the projector indicated that carefully designed film material presented by such a device can enable airmen to perform lengthy and exacting bench check operations accurately with little or no previous instruction or practice.

25. Hooprich, E. A. & Steinemann, J. H. An Investigation of the Utility of a Conversion Chart as a Job Aid for Electronics Technicians. San Diego: U. S. Naval Personnel Research Activity, Technical Bulletin STB 66-13, November 1965. (AD 624 608)

As a part of continuing research to increase the effectiveness of Navy training, an experiment was conducted to determine if a wallet-sized conversion chart would be a practical and convenient job aid for electronics technicians in training and on the job. Three groups of Navy personnel were used as subjects: 42 experienced technicians, 30 experimental ET School trainees, and 30 personnel with little or no electronics training. The criterion used to evaluate the effectiveness of the job aid was a 10 item measurement conversion test. One-half of each experimental group was allowed to use the conversion chart while taking the test, while the other half was not permitted to use any aid. The major finding was that those trainees using the conversion chart did significantly better on the test than those trainees not using it, and they also did as well as experienced technicians using or not using the chart. Questionnaire responses indicated that the subjects considered the conversion chart to be better than other similar aids and to be of value in the job or training situation after only brief instruction and practice. Distribution of the chart to Navy technical personnel was recommended, and proposed formats for the cards were presented.

26. Industrial Applications Human Factors Research Abstracts. Autonetics Division of North American Aviation, Inc., P5-1698/3111, 1966.

This is a company publication containing abstracts of 18 reports dealing with human factors studies having industrial applications issued between September 1963 and April 1966. The majority of the abstracts deal with studies in the quality control/inspection area.

27. Jacobsen, T. L. & Williams, R. A. "Audio-Visual Concepts in Industrial Manufacturing." Mechanical Engineering, August 1963, 85, 46-49.

This report discusses the benefits of using audiovisual aids in the manufacturing process. Among the benefits cited were reduction in training time for new employees, removing the training burden from experienced assemblers, and broadening the scope of duties that assemblers are able to perform. Uniform procedures can be developed with the same quality control criteria displayed to both assemblers and inspectors. To allow for learning that takes place on the job, Jacobsen describes the use of three different audio instruction tapes (a) training tape with complete instructions; (b) standard tape with condensed instructions; and (c) "bikini" tape having only the critical precautions. Performance with this last tape is envisioned as a prestige symbol and a motivating factor.

28. Kaplan, D. H. "Considerations in the Design and Installation of Cockpit Checklists, Placards and Manuals." Aero. Engineering Review, September 1951, 10, 10-16.

This article is concerned with the design, installation, and adequate utilization of cockpit checklists, placards, and manuals. A discussion based on relevant research is presented in terms of the following aspects of the problem: location, legibility (brightness, visual angle, observation interval), illumination under night visual conditions, the variations in checklists and manuals. A series of specific recommendations is offered concerning design, utilization, and experimentation with checklists, placards, and manuals.

29. Kravitz, S. "For That Special Problem, Design Your Own Slide Rule." Product Engineering, February 28, 1966, 37, 74-77.

The author suggests that where a few selected formulas are frequently used it may pay to design and even build a special slide rule. As a job aid, the use of a special slide rule can avoid much of the repetitive calculations, produce more rapid answers, and in some cases obtain more accurate values than with a standard slide rule. Normally, a lesser degree of skill and mathematical capability are required to operate the special slide rule. The key question is whether the formula lends itself to a slide rule solution. The article deals at some length in formula conversion plus a new mathematical technique for positively determining whether or not the formula can be put into slide rule form. A description of how to build a slide rule and information on where to obtain special slide rules are also provided.

30. Losee, J. E., Allen, R. H., Stroud, J. W., Ver Hulst, J. A Study of the Air Force Maintenance Technical Data System. Wright-Patterson Air Force Base, Ohio: 6570th Aerospace Medical Research Laboratories, Aerospace Medical Division, AMRL-TDR-62-85, August 1962.

This research involved an extensive literature search and review of applicable regulations, specifications, and selected technical orders; visits to Air Force installations and agencies to interview management and operating personnel and to survey a large representative group of Air Force maintenance technicians; a survey of technical publication sections of contractors; and an experimental evaluation of troubleshooting presentations. The findings highlight the impact of management on the procurement of accurate, timely, and economical data and identify areas in which management was found to be deficient. The report points out specific shortcomings in the data, their presentation, distribution, and use. It is observed that the eventual solution to the problem of maintaining the most complex system may well be automatic collection, storage, and retrieval of troubleshooting and repair information. Twenty recommendations are proposed to improve management of the overall Air Force Technical Order system and to enhance the quality, usefulness, and timeliness of the data produced.

31. Lumsdaine, A. A. & Hoehn, A. J. Behavioral Guides for Improving Utilization and Job Performance of Technical Personnel. Paper presented to the 65th Annual Convention of the American Psychological Association, September 1957.

Improvements in communicating job information through specifically designed handbooks, audiovisual media, and other forms of "behavioral guides" are described as capable of improving job efficiency and conserving skilled manpower by expanding the range of technical activities requiring only minimum formal training. These performance aids provide simplified, standardized, step-by-step instructions for performing exacting troubleshooting, alignment and related operations. Illustrations of such guides are presented, along with preliminary data on resulting increases in job efficiency and suggestions for research to improve the design and use of behavioral guides.

32. Maloney, R. T. Portable Microvisual Systems. Berkeley, California: Lederer, Street and Zeus, 1966.

This book deals with the retrieval of pictorial information using portable systems. Major emphasis is directed toward the description of portable microfilm systems; however, a description of videotape and facsimile systems is also provided. Applications of a number of portable microvisual systems are described.

33. National Security Industrial Association. The Modern Technical Manual. Proceedings of January 1964 West Coast Meeting, Technical Publications Panel, NSIA Maintenance Advisory Committee.

This is a report on a symposium held to direct attention to the imperative need to effect a major cost reduction in maintenance of military weapons through a revolutionary change in the concept, character, form, and function of technical manuals. A major contributor to the symposium, G. L. Belleville, reported on new methods and processes for storage, retrieval, and display of technical manual data at the point of use. The devices discussed included rear projection units, hard-copy printers, TV monitors, computer printout equipment, and portable readers.

34. Newman, J. R. Extension of Human Capability Through Information Processing and Display Systems. Santa Monica: System Development Corporation, December 7, 1966.

The development of on-line and time-sharing computer usage is described as having a significant effect on extending the capability of human performance. A study is reported in which problem solvers were provided with computer and display aids for aiding short-term memory; eliminating information thought to be unimportant; and recoding raw data into other units. Performance for this group exceeded a control group, and superiority persisted when the aids were taken away. It is concluded from this study and other work discussed that providing people with computer and display aids that overcome their limitations - memory and the ability to manipulate, recode, and transform data - can expand problem solving and decision making abilities tremendously, and has a straightforward application to industry.

35. Olson, P. T. Nomograms for Army Manpower Policy Evaluation. Washington, D. C.: U. S. Army Personnel Research Office, June 1966. (AD 640 005)

This report provides a series of charts or nomograms which have been developed by the U. S. Army Personnel Research Office for use in evaluating manpower policy alternatives. Manpower flow models were developed to represent the the Army's personnel system under varying requirements and restrictions with respect to types of duty tour, flow of personnel, duration of tours, allocation of personnel, and alternation policy. From models showing the personnel system in steady state, a series of nomograms or charts were constructed to facilitate the evaluation of alternative rotation policies in the context of contemplated modifications in the allocation of forces. The nomograms presented show the steady-state relationship between allocation percentages overseas and in the continental U. S. for various tour lengths and selected assignment policy alternatives. The charts can be used by management personnel to arrive at estimates of the effects of a given policy alternative without recourse to a computer and without working through the mathematical developments. The nomograms were employed in a recent staff study concerned with the number of men needed in particular service categories to support a prescribed rotation policy.

36. Proceedings of Air Force/Industry Data Management Symposium. Beverly Hills, California, September 28-30, 1965. Norton Air Force Base, California: Ballistic Systems Division, 1965. (AD 626 032)

Several papers presented under the symposium section entitled Advanced Concepts for Data Storage, Retrieval, and Communication Techniques cover recent technical advances in the storage and retrieval of data with examples of successful applications. Subjects discussed were: development of micro-image recording techniques; including recent application in videotape, photochromic coated film, and thermoplastic film; and use of a computer to provide troubleshooting and fault isolation information to electronics mechanics.

37. Proceedings of the Conference on Engineering Systems For Education and Training. June 14-15, 1966. Washington, D. C.: National Security Industrial Association 1966.

The views of governmental leaders and prominent researchers on a wide variety of educational and manpower issues were presented at this conference. The majority of discussion pertained directly to the problems of education, but the related issue of performance aiding was touched on by a number of speakers. The Honorable Thomas D. Morris, Assistant Secretary of Defense (Manpower), stated the objective of providing more information on an "as needed" basis, both for training and for use on the job. Colonel Triner of the Air Force stressed the use of computer technology for making pre-formulated solutions available to personnel in the job situation.

38. Rees, D. W. & Copeland, N. K. The Effects of Serial Position in Checklist Design. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, WADC-TR-59-552, September 1959. (AD 231 990)

An experiment was conducted to determine (1) whether serial position effects occur in the use of checklists, and (2) whether these effects can be modified. Subjects responded to a serial presentation of instructions by actuating switches. Two checklists of instructions were tested: a high and a low generalization list. The two criterion measures of performance were time spent observing the list (search time) and number of errors made. Results indicated that serial position effect does occur when search time is the criterion in checklist utilization. This effect can be reduced by isolation techniques; i.e., typographical arrangement of the material.

39. Rees, D. W. & Kama, W. N. Size of Tabs: A Factor in Handling of Guides and Check-lists. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, WADC-TR-59-158, March 1959. (AD 213 595)

To obtain information pertaining to the design of index tabs as used on checklists to facilitate handling, an experiment was performed in which subjects were required to pick up a checklist from a thighboard. The experimental variables were (1) size of tabs, (2) encumbrance conditions (bare hands and work clothes, gloves, gloves and fully inflated MC-3 partial pressure suits), and (3) tab position (top, center, or side of list). Reaction times in using tabs to locate information were studied by analysis of variance methods for effect of the variables. Increasing tab size resulted in overall improved performance. Presence of tabs was a significant improvement and as tab size increased, facility of access increased.

40. Rigney, J. S., Fromer, R., Langston, E. T., & Adams, H. C. Evaluation of an Experimental Fault Location Device: I, Fault Location by Radio Operators. Los Angeles: University of Southern California, Department of Psychology, Electronics Personnel Research Group, Technical Report 43, August 1965.

An experimental fault locator (XFL) was developed to be used as a job aid by shipboard personnel responsible for corrective maintenance of a radio transceiver. The XFL is a small, circular, plastic job-aid which incorporates circuit-front panel relationships essential for fault localization. This report describes the XFL and presents the results of the first of 2 evaluative studies. Twenty radiomen responsible for operating the AN/URC-32 aboard their ships were taught how to check out the front panel and how to use the XFL in a three-hour training session. Next, they were given six test problems to solve. They were allowed as many trials to solve each problem as they could complete in one hour. The percentage of subjects solving the problems on the first trial was quite high; this percentage increased on the second trial, and a very small percentage failed to obtain a correct solution within the one hour time limit. These results demonstrate that operators, who have had minimum electronics training, can use the XFL successfully to perform fault location on the AN/URC-32 transceiver. The XFL opens the way for non-maintenance personnel to share part of the maintenance burden with the very much overburdened ET, if this is considered to be a desirable management policy.

41. Rigney, J. W., Fromer, R., Langston, E. T. & Adams, H. C. Evaluation of an Experimental Fault Location Device: II. Fault Location and Isolation by Experienced Electronics Technicians. Los Angeles: University of Southern California, Department of Psychology, Electronics Personnel Research Group, Technical Report 44. September 1965.

Three groups of ETs were given the same task, that of isolating a malfunction to a faulty component. The XFL Group had to use the fault locator (See reference No. 40). The FP Group was given three hours of special instructions on the transceiver but no instructions on the fault locator. The Control Group was not given any special instructions regarding the transceiver or the fault locator. One-hundred percent of the XFL Group, 90% of the FP Group and 30% of the Control Group solved the first problem within the 3 hour time limit. The mean times for successful solution in each group were 51 minutes, 48 minutes, and 130 minutes, respectively. Ninety percent of the XFL Group, 50% of the FP Group and 50% of the Control Group solved the second problem within the 3 hour time limit. The mean times for successful solution in each group were 62 minutes, 66 minutes, and 80 minutes, respectively. The results of this study and the previous one demonstrate the effectiveness of the fault locator as a maintenance job aid. Both Radiomen and Electronics Technicians can be taught to use the device in a very short period of time and have shown a high degree of success in its use.

42. "Robot Instructors Win Friends and Speed Assembly." Factory, November 1960, 96-99.

The robot referred to in this article is an Audio-Visual (A-V) Unit. A discussion is presented of its development and application to assembly line production by several different companies engaged primarily in electronics manufacturing. Details on how A-V units operate and their application using varying features of the system are portrayed in some length. A key factor in the success of the program is in the preparation of slides, clarity of script and the sequencing of the two into an instruction which minimizes the need to tax the operator's memory. At the time of this article, one company revealed that with very few exceptions the A-V systems have been enthusiastically received. The reason for acceptance appears to be that the unit reduces the job to a non-decision making, mechanical process. Provided with increased assurance of doing the right job and relieved of the chance of misinterpreting text or drawings, the operator is relaxed and experiences less fatigue. While the skilled operator appeared to resent the rote process that the A-V unit places on him, most other operators indicated a marked appreciation for the solitude obtained by eliminating distracting sounds when using earphones. Quotations in this article from one company indicated that before A-V use, experienced operators achieved only about 60% of work standards with less experienced operators falling below the 60%. With A-V, practically every operator is said to achieve 90 to 100% of work standards consistently with defect rate reduced as much as 99% and rework areas virtually eliminated. Another organization was quoted as experiencing a 50% cut in learning time; 80% decrease in attention required from leadman; improved product quality and increased worker's versatility. Still another company was reported to have reduced inspection manpower and rework by 85%, and supervision by 70%.

43. Rogers, J. P. & Thorne, H. W. The Development and Evaluation of An Improved Electronics Troubleshooting Manual. Alexandria, Virginia: George Washington University, Human Resources Research Office (HumRRO), Technical Report 65-1, March 1965. (AD 614 606)

A maintenance manual differing in organization and content from conventional manuals was developed to test the hypotheses that improvements in those areas would directly affect quality and quantity of electronic troubleshooting activities. The "test" manual and a "standard" manual were used by two matched groups of military technicians to troubleshoot a set of electronic malfunctions. Results of the study indicated that relevancy of content, degree of detail, and functional accessibility of information can significantly affect speed and effectiveness of electronic troubleshooting activities.

44. Sheridan, T. B., Duggar, B. C. & Mayer, Sylvia. Design and Use of Information Systems for Automated On-The-Job Training II. Design of Self-Instructional Features. L. G. Hanscom Field, Mass: Electronic Systems Division, U. S. Air Force, ESD-TDR-64-234, January 1964. (AD 602 042)

This second in a series of five reports is concerned with human engineering factors in the design of information systems. Theories, methodology, and design principles for implementing self-instructional features in information systems are described. Several techniques and considerations relating to aiding the sequencing of actions, logic analysis, and query-reasoning behavior are provided.

45. Sheridan, T. B. & Mayer, Sylvia. Design and Use of Information Systems for Automated On-The-Job Training I. Conceptual and Experimental Approaches. L. G. Hanscom Field, Mass: Electronics Systems Division, U. S. Air Force, ESD-TDR-64-234, December 1963. (AD 602 041)

This report discribes the first year's efforts of a project covering exploratory work on automated training for information systems. Exploratory developments on laboratory models of automated training subsystems are described. The ultimate goal is to provide future information systems with the capability to train their users on the job.

46. Shriver, E. L., Fink, C. D., & Trexler, R. C. FORECAST Systems Analysis and Training Methods for Electronics Maintenance Training. Alexandria, Va: George Washington University, Human Resources Research Office (HumRRO), Research Report 13, May 1964. (AD 441 248).

The report presents results of a continuing study, titled FORECAST, undertaken to improve the efficiency of the electronics systems troubleshooting process. One of the theses of this study is that there is a discontinuity between troubleshooting theory presented in basic electronics courses and maintenance manuals, and the practices that must be followed in on-the-job fault isolation; and that these deficiencies in training and job aids can be alleviated by introducing a "bridge" between theory and practice. The "bridge," consisting of special training courses, classroom training aids, and job performance aids was demonstrated to be more effective than traditional solutions. Trainees acquired as much information in a 12 week FORECAST course as those taking a standard 30 week course in one experimental study; while graduates of another FORECAST course performed 40% better than traditional graduates. FORECAST job performance troubleshooting aids were developed to permit rapid access of relevant information only. The author stated that application of FORECAST training and job aids can significantly affect quality of job performance.

47. Shriver, E. L. & Trexler, R. C. Application and Test of the FORECAST Concept of Electronics Maintenance on Navy LORAN Equipment. Alexandria, Va: The George Washington University, Human Resources Research Office (HumRRO), Technical Report 65-3, May 1965. (AD 616 753)

Results of an application study of the FORECAST system to naval electronics personnel trained to maintain a LORAN (long range navigational) system are presented in this report. The FORECAST concept is a collection of policies, strategies, methods, techniques, and services developed for the purpose of improving the quality of military electronic maintenance. The central theme of the FORECAST program is that existing electronics courses and troubleshooting job aids presented in maintenance manuals are primarily oriented to electronics theory that is of limited value to the real world. Content of training courses and job performance aids developed under the FORECAST program "bridge" the gap between theory and practice. FORECAST training and standard training course work were administered to two groups of electronics students. The FORECAST group performed significantly better in identifying malfunctions in a performance test than those receiving conventional training.

48. Teel, K. S. & Chaney, F. B. Improving Inspector Performance Through Training and Visual Aids. Paper presented to the 74th Annual Convention of the American Psychological Association, September 1966.

The purpose of this study was to evaluate, singly and in combination, the effectiveness of a 4-hour training program and a set of visual aids designed to improve the performance of machined parts inspectors. The criterion used was the percentage of true defects detected in a selected sample of machined parts. Findings indicated that: use of training alone resulted in a 32% increase in defects detected; use of visual aids alone resulted in a 42% increase; and use of both resulted in a 72% increase; while performance of the control group did not change.

49. Tilley, K. W., Knight, M. A. & Stainer, F. W. "Training for Fault Diagnosis; The Use of Job Aids." Ergonomics, 9, January 1966, 88.

This is an abstract of a presentation to the Ergonomics Society Meeting on Occupational Training at Berkbeck College, London, on 8 July 1965. Two types of job aids, circuit diagrams and fault finding guides, were identified as being under study.

50. Topmiller, D. A. Application of Behavioral Science to Performance Aid Development. Wright-Patterson Air Force Base, Ohio: Aerospace Medical Research Laboratories, Air Force Systems Command, AMRL-TR-65-146, August 1965.

Four classes of variables relevant to behavioral research on the development of performance aids are outlined within an historical framework, with supporting empirical research. The four classes of variables are: (1) legibility and format variables; (2) variables associated with processing printed numeric information; (3) variables associated with troubleshooting informational processing and display systems; and (4) variables associated with the physical configurations of performance aids. Some predictions are made for future trends in performance-aid behavioral studies; e.g., improving the legibility and format of technical publications, configuring maintenance information to reduce weight and bulk, conducting cost-effectiveness studies; and exploiting the rapid data processing functions of computers as decision aids.

51. Travers, R. M. W. (Ed). Research and Theory Related to Audiovisual Information Transmission. University of Utah, Bureau of Educational Research, July 1964.

A distinction is made between the implicit theory reflected in the products of creative designers of audiovisual aids and the principles derived from controlled observations and studies of the transmission of information. The findings from the empirical work were found to put in question many of the current practices and textbook generalizations. It is reported that differences shown for the efficiency of audio, visual, and audiovisual media are dependent on such factors as rate of presentation, nature of the material, or reading ability. It is also suggested that simultaneous transmission through more than one sensory modality presents problems of human overloading that may or may not be solvable in any particular application. Multiple sensory modality inputs are likely to be of value only when the rate of information input is very slow.

52. U. S. Army Test & Evaluation Directorate. Final Report of Test of Audio-Visual Information System (A-VIS). White Sands Missile Range, New Mexico: NIKE X Report No. 65-2, September 1964. (AD 608 308)

Objective and subjective data were collected to evaluate use of an experimental audiovisual information system (A-VIS) for missile system maintenance. Five modes of presentation were used: audiovisual, visual, audio, programmed technical manuals, and conventional technical manuals. The results tended to show a marked superiority of visual and programmed technical manual modes, with conventional technical manuals and audiovisual presentations scoring low. The principal contribution to the superiority of the automated modes was in informational content. However, the contribution made by the automatic video retrieval system was significant, and enhanced the value of the data programs. Several hypotheses were advanced to explain the poor showing of audio presentation: (1) the use of two senses simultaneously under the requirement to react with some time urgency tends to induce a measure of confusion; (2) audio presentation reduces the rate of information transmission and it is not possible to scan audio in search of a pertinent detail; (3) the female audio voice used did not inspire confidence among the technicians.

53. Warren, N. D., Schuster, D. H., French, R. S., Latina, R. J. & Nelson, R. A. Development and Evaluation of a Troubleshooting Aid for Flight Line Maintenance of a Complex Electronic System. Lackland Air Force Base, Texas: Air Force Personnel and Training Research Center, AFPTRC-TN-58-1. (AD152 110)

A study was conducted to determine whether an effective and logical troubleshooting aid for complex electronic systems could be developed for use by relatively inexperienced flightline mechanics. In this study, the investigation of the feasibility of such a troubleshooting aid was made for the K Bombing Navigational System. A Trouble Locator in booklet format was developed and evaluated. A "procedure-oriented" approach to identify malfunctioning loops supplemented by a "symptom-oriented" approach for within-the-loop troubleshooting was found to be desirable; both procedures were incorporated in the final Trouble Locator. A limited evaluation in the field and on a bench mockup demonstrated that this type of troubleshooting aid for complex electronic systems was practical.

54. Whitehead, L. W. "Simple Nomographs Are Easy to Draw." Power Engineering, 70, March 1966, p. 90.

Whitehead suggests that nomographs can be of definite help for repeated calculations and to extend results from tests. The construction of a simple nomograph for adding numbers is described in detail.

55. Wulff, J. J. & Berry, P. C. "Aids to Job Performance" In R. M. Gagne (Ed) Psychological Principles in System Development. New York: Holt Rinehart and Winston, 1962, pp. 273-298.

Wulff and Berry discuss the design and development of job aids for system operation. The primary objective of the chapter is to show the relationship between the practical problems of job aid design and the more basic psychological principles and research problems in human behavior. The chapter provides background information on the development and use of job aids in man-machine systems, but the major emphasis is upon research problems underlying job aid design. The authors draw a parallel between the function that a job aid serves for human performance and the function of a program for a computer. Stimulus control of human performance is conceived as the major psychological problem in the design of job aids. Rather than attempting to define the total range of human performances in systems, it is argued that job aid research should be directed toward identifying the different kinds of performance change that can be effected by stimulus control through job aids, and relating these classes of change to the characteristics of job aids.

APPENDIX B

REFERENCE INDEXES SURVEYED

Applied Science and Technology Index	1963-1966
Business Periodicals Index	1962-1966
Engineering Index	1964-1965
Psychological Abstracts	1927-1965
Readers Guide to Periodical Literature	1962-1966
U. S. Army Human Factors Engineering Bibliographic Series, Volume I, May 1966	1940-1959

APPENDIX C

SOURCES OF BACKGROUND INFORMATION

Organizations and Individuals Active or Interested in the Job Performance Aid Field

Aerospace Medical Research Laboratories
Wright-Patterson Air Force Base, Ohio

Dr. R. L. Morgan

Applied Science Associates
Valencia, Pennsylvania

Dr. J. D. Folley
Dr. T. Elliott

Autonetics, A Division of North American Aviation, Inc.
Fullerton, California

Dr. K. S. Teel
Dr. F. B. Chaney

U. S. Army Air Defense Human Research Unit
Human Resources Research Office
Ft. Bliss, Texas

Dr. H. L. Ammerman
Dr. J. P. Rogers

U. S. Naval Personnel Research Activity
San Diego, California

Dr. E. E. Dudek, Technical Director
Dr. E. I. Jones, Director
Training Research Laboratory

University of Southern California
Los Angeles, California

Dr. J. W. Rigney, Principal Investigator
Electronics Personnel Research Group

APPENDIX D

INTERVIEW AND OBSERVATION OUTLINE*

I. Identifying Data

- A. Organization
  - Name
  - Address
  - Date of Visit
- B. Personnel Contacted
  - Name
  - Job Title

II. Description of Performance Aid Used

- A. Description of Task Supported
  - Summary -
  - Major Task Characteristics
    - Procedural
    - Repetitive
    - Variable
    - Frequency per Shift
    - Time to Complete
  - Major Operations Performed
    - Inspection
    - Troubleshooting
    - Conversion

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* The above form was not intended to cover the specific details of the entire interview, but rather was designed to serve as a frame of reference for guiding the interview and observation. In keeping with the exploratory nature of the survey, the items on the form served as the stimulus for a variety of additional questions during the lengthy interview and observation session.

Major Operations Performed (Continued)
- Computation
- Assembly/Disassembly
- Other

B. Type of Aid Used
- Narrative
- Checklist
- Tabular
- Calculating Chart
- Graphic
- Drawing
- Film
  - B&W
  - Color
  - Slides
  - Still Photos
  - Motion Silent
  - Motion Sound
- Audio
- Tape
- Record

C. Characteristics of Aid
- Physical:
- Functional:
- Location:

D. When and How Used

E. How Long in Use

F. Attitudes Toward Performance Aid
- Incumbents
- Supervisors

III. Impact on Task Performance
- Quality
- Quantity
- Reliability

IV. Impact on Job Requirements
- Selection
- Training

V. Problems in Using Aid

Possible Improvement

VI. Recommendations for New Aids